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HISTORY OF INDUCTION.

THE

AMERICAN CLAIM

TO

THE INDUCTION COIL

AND

ITS ELECTROSTATIC DEVELOPMENTS.

IN THREE PARTS.

I.—INDUCTION AND INDUCTION APPARATUS.
II.—CONTACT OR CIRCUIT-BREAKERS.
III.—ELECTROSTATIC PROPERTIES OF INDUCTION COILS AND MAGNETO-ELECTRIC MACHINES.

76

WASHINGTON:
INTELLIGENCER PRINTING HOUSE,
401 and 403 D Street, near 7th.
1867.

FIG. 1.

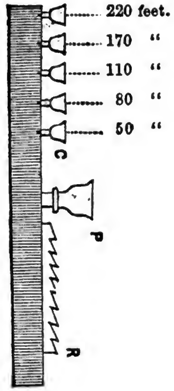


FIG. 2 BIS.

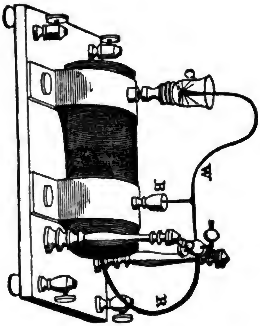


FIG. 3.

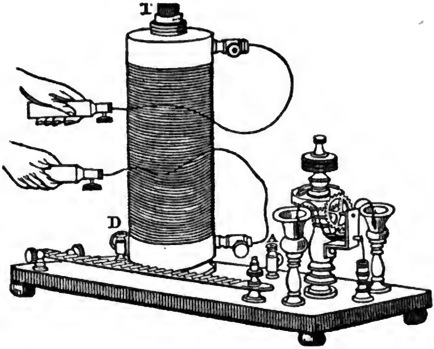
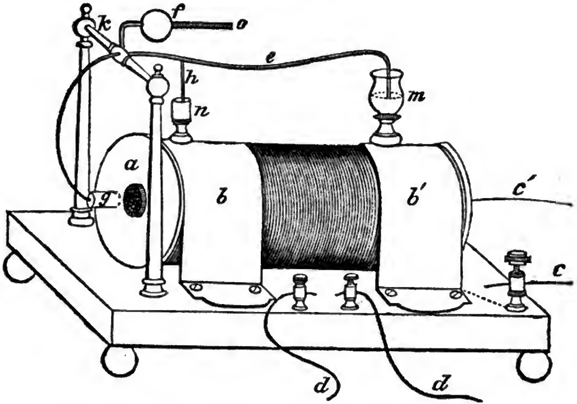


FIG. 2.



Page's Electrostatic Coil. April, 1838.

FIG. 4.

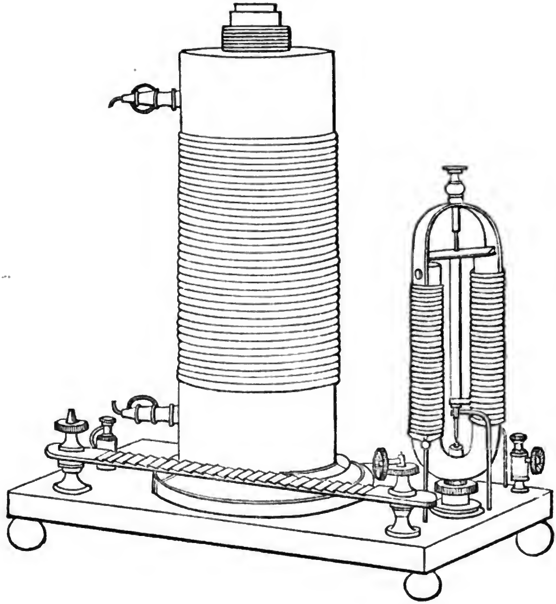


FIG. 5.

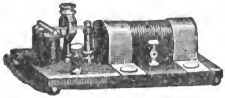


FIG. 6.

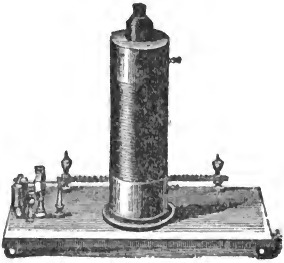


FIG. 7.

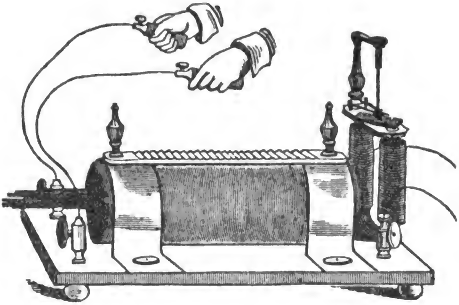


FIG. 8.

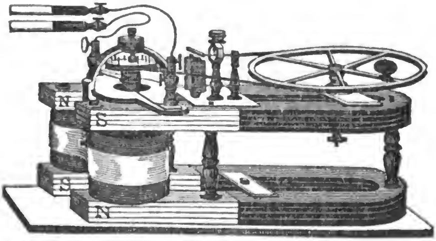


FIG. 9.

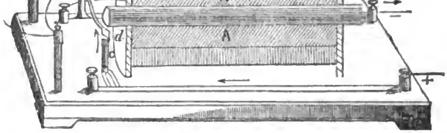
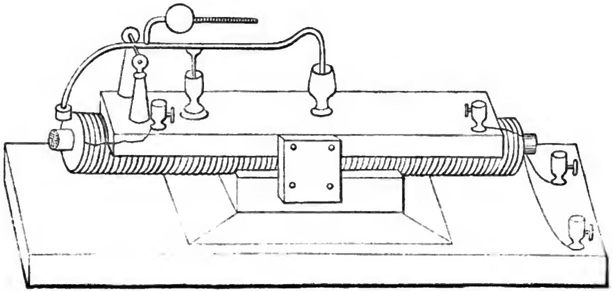


Fig. 10.



Page's Electrostatic Coil of May 4, 1838.

HISTORY OF INDUCTION.

THE

AMERICAN CLAIM

TO

THE INDUCTION COIL

AND

Grattan

ITS ELECTROSTATIC DEVELOPMENTS.

By Charles G. Page.

IN THREE PARTS.

I.—INDUCTION AND INDUCTION APPARATUS.
II.—CONTACT OR CIRCUIT-BREAKERS.
III.—ELECTROSTATIC PROPERTIES OF INDUCTION COILS AND MAGNETO-ELECTRIC MACHINES.

WASHINGTON:
INTELLIGENCER PRINTING HOUSE,
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1867.

1868. May 25
By mail

HISTORY

OF

VOLTA-ELECTRIC AND MAGNETO-ELECTRIC

ERRATA.

Page 9, line 8, for "pole," read *pile.*

Page 21, line 18, insert *in* after the word "being."

Page 33, line 8, for "presented," read *prevented.*

Page 44, lines 6 and 7, for "somewhat less than four-tenths," read *about one-eighth.*

Page 47, line 15, for "preparation," read *perfection.*

Page 63, line 25, after the word "either," insert *side.*

Page 102, line 22, after the word "to," insert the word *the.*

Page 115, line 21, for 1854, read 1864.

obtained; and, in cases of the medical application of galvanism, it must prove far more convenient than the ordinary methods." The "ordinary methods" at that time were the cumbersome galvanic batteries, the frictional electric machine, and the magneto-electric machine. The description of Prof. Henry's apparatus, hereafter noticed, and that of Prof. Page, were both received in London by Mr. Sturgeon,

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HISTORY

OF

VOLTA-ELECTRIC AND MAGNETO-ELECTRIC INDUCTION AND INDUCTION APPARATUS.

PART FIRST.

The first galvanic or Volta-electric induction apparatus by which shocks, together with other indications of electricity of high intensity, were obtained from a *secondary coil*—that is, a coil not included within the battery circuit—was made by Prof. Page. This was a regularly organized apparatus of remarkable power, a full description of which was communicated to Silliman's Journal, under date of May 12, 1836, with the following caption: "*Method of increasing shocks, and experiments with Prof. Henry's apparatus for obtaining shocks and sparks from the Calorimotor, by C. G. Page, Salem, Mass.*" This apparatus (Fig. 1) was so graduated that the strength of the induced current could be varied at pleasure; was furnished with mechanical and *automatic* circuit-breakers, and the now celebrated spark-arresting circuit-breaker, and produced secondary or induced currents from coils outside of the battery or primary circuit, and of sufficient intensity to charge a Leyden jar. The communication closes with this remark: "We have, then, in this instrument a battery by itself, from which shocks of all grades can be obtained; and, in cases of the medical application of galvanism, it must prove far more convenient than the ordinary methods." The "ordinary methods" at that time were the cumbersome galvanic batteries, the frictional electric machine, and the magneto-electric machine. The description of Prof. Henry's apparatus, hereafter noticed, and that of Prof. Page, were both received in London by Mr. Sturgeon, the editor of the Annals of Electricity and Magnetism, at the same time, and published side by side, and with the following comment by the editor: "Mr. Page's variations of Prof. Henry's experiments are very important."—(*Sturgeon's Annals, May*, 1837.) They have proved to be *important*, inasmuch as the principle of construction adopted in the Page coil is that, *of an economical use of battery power, which has been applied since that time in every form of induction apparatus, whether for remedial or philosophical use and research.* The principle is simply this: *In order to obtain induced currents of high intensity from a battery of a single or only a few pairs of plates, an extra and much longer circuit must be employed for the induced current than that used to transmit the battery current; or, more briefly, the induced or secondary circuit must be much longer than the inducing or primary circuit.* In Prof. Henry's experiments only a primary circuit was used. In Faraday's celebrated experiments on induction the primary and secondary circuits were of nearly equal length—the secondary circuit being actually a little shorter than the primary by a foot and one-half. The current he obtained from his secondary circuit had less intensity than the terminal secondary or induced current from his primary circuit. Hence he makes no mention of shocks received from the secondary circuit, while he obtained them freely from his primary circuit. In Faraday's first experiments, in 1831, and in his experiments in 1834, both relating to the subject of induction, he used the same arrangement of his coils; and it is somewhat remarkable that, in the multitude of his experiments, it did not occur to him to try the effect of a longer circuit for his secondary coil. In his beautiful series of experiments in 1831, wherein he demonstrated the induction of currents, and, also, in his ninth series, published in 1834, on the induction of a current on itself, he contemplated no practical application of the principles developed, and resorted to no means of increasing the power of the induced currents, being content with the mere exhibition of the current itself by feeble manifestations.

The credit of the first induction coil has generally been ascribed by European authors to Prof. Callan, of Maynooth College, Ireland. Prof. Callan's experiments and apparatus were, indeed, considerably in advance of his European cotemporaries, but were subsequent to those of Prof. Page; and, in order more fully to establish the claim of Prof. Page to the first induction apparatus, and to give every discoverer, inventor, and contributor his true chronological position, a resumė is here given of the progress of the subject of induction since its first discovery by Faraday, who, for the sake of distinction, from static-electrical induction adopted the term Volta electric induction. In 1825 Faraday attempted to prove, experimentally, Volta electric induction, and failed, although the subsequent verification of his theory was made by very similar experiments and arrangements.—(*Phil. Trans.*, 1832, *page* 162.) In November, 1831, he read before the Royal Society an account of his discovery of the induction of currents, showing that the passage of a galvanic current in one wire induced a momentary current in a contiguous wire, and that the movement of the wire, transmitting a current, to and from another wire, also developed momentary currents in the latter. In the same paper he also announced the interesting discovery of the development of electricity by magnetism, the electric currents being produced by the development of electro-magnetism and its cessation, and, also, by the motion of a steel magnet to and from its keeper—the latter being surrounded by a coil of wire, connected with a remote galvanometer. With the electro-magnet he obtained a slight spark by using charcoal points, but failed to obtain the spark from the experiments with the steel magnet. By using a very powerful loadstone he was able to convulse a frog's leg, and he thought he produced a slight sensation upon the tongue. This species he termed magneto-electric induction. The currents in neither case were of sufficient intensity to produce a shock, although he used very large batteries. It is a very remarkable circumstance that, in each experiment instituted, with a view to develop the induced current in a separate or secondary coil, Faraday should have used the longer coil for the battery circuit and the shorter for the secondary circuit. Simply reversing the order of his coils would have given him quite a difference in his results. From the secondary, by Volta-electric induction, he says, "I could obtain no evidence by the tongue, by spark, or by heating of fine wire or charcoal; nor could I obtain any chemical effects." The current was indicated only by the galvanometer and its magnetic effects.

On the 30th March, 1832, Mr. Forbes, of Edinburgh, obtained a spark from the use of the steel magnet. (*May No. Annals of Philosophy,*) also (*Sill's Journal, vol.* 22, *page* 408.)

In the latter part of June, 1832, Prof. Henry commenced experiments on magneto-electric induction, of similar purport with those of Faraday, and was more successful in the production of sparks. These were communicated in the July No. of Silliman's Journal for 1832. In the same No. Prof. Henry announced the interesting facts, that when a very short wire (a foot in length) joined the poles of a small battery, in such a condition as to give no spark with this wire, a wire thirty or forty feet in length would give a bright spark on breaking the circuit, and that the "effect appeared to be somewhat increased by coiling the wire into a helix." The battery, in this case, was spoken of as "a small battery," the number of pairs of plates, a very important point, not being mentioned. It is stated that, "if moderately excited by diluted acid, it would not give a spark with a wire one foot in length on breaking the circuit," but if the action of the battery be very intense, a "spark will be given by a short wire." The inference is rather in favor of one pair of plates, or perhaps several pairs joined as one, inasmuch as one foot of wire was used to join the poles.

Prof. Henry referred this phenomenon to the class of Volta or magneto-electric induction. No shock was obtained in either the experiments of Henry or Forbes.

In the early part of 1833, Prof. Dal Negro asserted that the "separating spark of a Voltaic pile originated ,at least in part, from magneto-electricity, and hence would be more intense if the conducting wire were coiled around a bar of iron." (*Annali delle Scienze, March and April*, 1833,) also (*Biblioth Univer., July and August.*) This was the first public announcement in relation to the augmentation of the spark of separation as produced by a coil *surrounding an electro-magnet*, and laid the foundation for the third species of *current* induction, which we shall call Volta magneto-electric induction. The three species, *Volta electric induction, magneto-electric induction*, and *Volta magneto-electric induction*, are, undoubtedly, results from the action of electricity; but, as they are all produced under different arrangements and conditions, it is important to preserve these distinctions.

On the 18th December, 1834, Faraday communicated to the Royal Society an interesting paper " on the influence by induction of an electric current on itself," containing an account of the discovery of the production of sparks and *shocks* from a single Voltaic pair. Faraday received his information on this point from Mr. William Jenkins, who must, therefore, in the absence of any other record, be considered the discoverer of this important and interesting fact. Faraday ingenuously relates the circumstance as follows: Mr. Jenkins informed him that, " if an ordinary wire of short length be used as the medium of communication between the two plates of a battery of a single pair of metals, no management will enable the experimenter to obtain an electric shock from this wire; but if the wire which surrounds an electro-magnet be used, a shock is felt each time the contact with the electromotor is broken, provided the ends of the wire be grasped, one in each hand." This discovery rests upon the same principle as that of Prof. Henry's, already cited, as announced by him in 1831; but its distinguishing interest and importance consists in the production of sparks and *shocks* from a *single* Voltaic pair. Faraday also announced the same in the November No. of the Lond. and Edin. Phil. Magazine for 1834. Faraday used two helices coiled around a pasteboard tube—one 96, and the other 94½ feet in length, the former to transmit the battery current, and the latter to exhibit the induced current. Sparks and shocks were obtained from the inducing or first helix, and sparks from the second helix, but *no shocks.* It will be noted here, that both the helices were about the same length. An iron bar was introduced in the pasteboard tube to increase the intensity of the induced currents.

On the 16th January, 1835, Prof. Henry made a communication to the Amer. Phil. Society on the same subject, and his paper, with the following title, was read on the 6th February, 1835. "*On the influence of a spiral conductor in increasing the intensity of electricity from a galvanic arrangement of a single pair.*"

This influence was exhibited in an interesting series of experiments by the aid of helices of wire, and the winding of a flat copper strip or ribbon into a spiral, the greatest length of which was ninety-six feet. With a large calorimotor of eight pairs, shocks were felt as far as the elbow.

In the latter part of 1835, Dr. Neef, of Frankfort on the Main, published in Poggendorff's Annals, vol. 36, page 352, an account of experiments for the purpose of obtaining a rapid succession of shocks by a mechanical contrivance called a "lightning wheel," for making and breaking rapidly the circuit with a Voltaic pile, both with and without the interposition of coiled conductors. The wheel consisted of a circular table or disc of copper 6½ inches in diameter, mounted to revolve on a vertical axis. The upper face of this disc presented thirty-six strips of wood, or other non-conducting material, inlaid, with strips of copper. A conductor resting upon the upper face over the strips, was for connection with one pole of the battery, the other pole being in connection with the bearings of the wheel. As the wheel was turned, the circuit was broken thirty-six times for every revolution. It was tried with a Voltaic pole, to obtain a rapid succession of contacts, and also with a coil of wire surrounding a bar of soft iron, and was found to produce novel and important physiological effects due to the rapid succession of small shocks. It was contemplated by Dr. Neef for use for medical purposes. The circuit-breaker was in reality a production of Mr. Wagner, a friend of Dr. Neef. It is the first recorded account of a mechanical circuit-breaker applied for this purpose. The apparatus was, however, cumbrous; and as only a Voltaic pile was used, and no secondary circuit around the electro-magnet employed, the action was too feeble and inconstant for practical application, and must have gone speedily into disuse. Dr. Neef revived the subject in 1839, after his introduction of an automatic circuit-breaker. It is interesting to note, that Dr. Neef suggests in this paper the use of galvanic baths, now so much in vogue.

Perhaps the experiments of M. Masson, of France, were in advance of those of Dr. Neef, both as regards the coil, its physiological effects, and the use of a mechanical circuit-breaker. Du Moncel, in his Exposé des Applications de l'Ectricité, 1856, says that "M. Masson was one of the first who perfected the apparatus for Volta-electric induction. That in 1836 he employed a toothed wheel (*roue dentée*) revolving against a metallic spring for breaking the circuit with a coil, and obtained currents of some intensity." We find a communication from M. Masson towards the close of the year 1837, in the Annales de Chemie, vol. 66, page 28, on this subject, in which he refers to his "*Memoire*" to the

French Academy, in June, 1835, as containing the substance of his paper. We also find, in the Compte Rendu, 1837, a report of M. M. Becquerel and Savary of the Séance of 27th of March, 1836, on the memoir of M. Masson, which they state was received soon after the discoveries of Faraday on the induction of a current on itself, were made known in Paris. This is somewhat indefinite; but as these discoveries were published in the latter part of 1834 and beginning of 1835, we may be safe in taking the date of June, 1835, for M. Masson's experiments. Becquerel's report mentions the coil of 1,400 feet of wire, the use of a number of pairs of Wollaston battery, and the toothed wheel circuit-breaker. Also the production of shocks of sufficient power to kill a cat. It is probable, therefore, that M. Masson preceded Dr. Neef, and that he was the first to obtain secondary currents of high intensity from a primary circuit by using an intensity battery, and to use a mechanical circuit-breaker in connection with the coil. M. Masson, in concluding his paper referring to the publication of Dr. Neef's experiments, says they were "made subsequent to his own." M. Masson's toothed wheel was revolved by a pulley, band and multiplying wheel. He did not employ a secondary circuit, and the great length of his circuit wire and extended batteries rendered the whole too cumbrous for medical uses.

In 1836 Prof. Page communicated to Silliman's Journal, vol. 31, page 137, a description of an induction apparatus, under the following caption:

"*Method of increasing shocks and experiments with Prof. Henry's apparatus for obtaining sparks and shocks from the Calorimotor, by* C. G. PAGE. Salem, May 12, 1836."

An engraving is given of the apparatus, and on reading the description it is found to be distinct from any which preceded it, in several important particulars. It announces the interesting and very important discovery, that the "*shock is very much increased* by breaking the circuit over mercury covered with water or with naptha." A description is given of *two mechanical circuit-breakers* for producing a rapid succession of shocks—one made of a rasp, and the other a revolving spur-wheel. A postscript to the article, dated SALEM, JUNE, 1836, describes an *automatic circuit-breaker,* consisting of Barlow's spur-wheel included in the circuit. It mentions the "charging of a Leyden jar by the secondary current," and the decomposition of water, together with several other novel and interesting experiments. But the most important feature of novelty is that of "*increasing shocks,*" as the caption indicates, by the use of a longer coil for the secondary current than that used to transmit the battery current, and also in producing shocks from a purely secondary coil exterior to the primary coil.*

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* Prof. Page, at the time of this announcement, was a medical student, and had no facilities at that time for obtaining a knowledge of the progression of electrical science in Europe. Information, however, of Prof. Page's experiments was carried to Europe by Francis Peabody, of Salem, Mass., and communicated to Mr. Sturgeon in advance of their publication here. Although Mr. Peabody withheld Prof. Page's name, yet he described Prof. Page's apparatus, (see Sturgeon's Annal's, vol. 1, page 59,) and not Prof. Henry's, while he gave the credit, as Mr. Sturgeon states, to "Prof. Henry, of Yale College." The mention of this little circumstance is of historical value, inasmuch as Mr. Sturgeon's notice of the discovery in his journal was dated September 24, 1836, and in the commencement of his article he refers back to the interview with Mr. Peabody, as "a week or two prior to the Bristol meeting of the British Association;" and Prof. Page's paper did not appear in this country until the January number of Silliman's Journal for 1837. The Bristol meeting was held in August, and a week or two before would date the information given by Mr. Peabody in the latter half of July, 1836. Prof. Page exhibited his coil in operation to Mr. Peabody before he left for Europe, and the betrayal of his mistake there is fixed by the following circumstance. Referring to a device of his own, Mr. Sturgeon says, (vol. 1, page 69,) "figure 16 is very unlike the apparatus which Mr. Peabody described." "Dr. Henry's apparatus consists of a long strip of sheet copper formed into one coil in the manner of a watch spring, having one of its extremities in connection with one of the plates of a large calorimotor, and about half-way between

In reviewing the history thus far given of induction, which is believed to be full as to all important facts and principles, we find no allusion whatever to an *intensity* circuit, independent of the primary or battery circuit. No mode whatever of increasing the intensity of a secondary current from a coil of wire or spiral of ribbon, except by enlarging the battery, and increasing its intensity as the length of the coil or spiral increased. The only instance of a secondary circuit at all, was in Faraday's experiments, and this was so employed as to furnish a secondary of less intensity than the secondary of the primary circuit. In fact, the portion of the secondary circuit, exterior to the primary circuit, was only one-half the length of the primary, the other half being coiled within the primary circuit, an arrangement of disadvantage for displaying the action of the secondary circuit. We find, moreover, no attempt to produce electro-static effects with a secondary current. The coil of Prof. Page consisted of a spiral of copper-ribbon, one inch wide, and 220 feet long, being 124 feet longer than the longest used by Prof. Henry in his experiments. The coil was placed in a wooden box, B, Fig. 1, through the cover of which projected six copper strips, connected with the spiral at various distances from the centre, each bearing a mercury cup, C C. The central cup P was large, and made of glass, for the better observation of the spark, and to receive water or any spark arresting liquid over the mercury. The various lengths of coil included between the intermediate cups were

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the extremities of the copper strip is connected the other Voltaic plate, and the person who experiences the shock is placed in connection with the two extremities of the coil." Now, this is a correct description of Prof. Page's apparatus, and *not* Prof. Henry's; for the mode of connecting the battery with the middle of the coil and taking the shock from the whole coil forms the distinguishing feature of Prof. Page's coil, and between his and Prof. Henry's, and every other coil which preceded it. This announcement of Prof. Page's coil undoubtedly gave the first impulse to the pursuit of the subject in Europe.

shown in numerals. The rasp R is shown placed on the box. This arrangement admitted of making the primary and secondary circuits of various lengths, and testing the maximum effects of batteries of different powers in producing currents of intensity. The only batteries mentioned were simple batteries, that is, single pairs of different sizes. But we are justified in an interpolation to the effect that several kinds of batteries were used, and that when mention is made of "charging a Leyden jar by the coil," it should have been stated that an intensity battery was used. It is contrary to the plan of this work to introduce facts which are not a matter of record. The insertion is here made, however, for the mere purpose of explanation and reconciliation, with a statement found in an unpublished letter from Prof. Page, forwarded for publication in Silliman's Journal Dec. 2d, 1837. This letter was returned to Dr. Page at his request, and contains on the back the following endorsement by Prof. Silliman: "Dr. Page, on Sturgeon's dynamic lines, received Dec. 8, 1837," and also an autograph note on the margin from Prof. Silliman, "congratulating Dr. Page on his success," etc. After a long discussion of Sturgeon's theory, the letter ends thus: "In concluding this paper, it gives me pleasure to announce that, after repeated trials and failures, I have at last succeeded perfectly in charging a Leyden jar by the action of the spiral, in connection with a *single pair* of plates." The spiral, by this time, was 320 feet long, (Sill's Journal, vol. 33, No. 2, page 355,) and a single pair of plates found to be capable of charging a jar, which it would not do when tried before. As the jar was *charged* before, it was of course effected by a battery of intensity, and not a single pair. The explanation has this value alone, that the intensity of the secondary current obtained in the first experiments with the spiral, seemed, when measured by other tests, hardly adequate to the charging of a jar so as "to produce shocks," and the explanation restores consistency to the statement.

In the previous October No. 1837, of Sill's Journal, page 355, Dr. Page described the passage of the secondary current between charcoal points "*before contact.*" In this letter allusion is made to "an unsuccessful trial to increase the length of this spark in vacuo, with a single pair of plates." That he had not tried it with an intensity battery, but expected then to find an increase." A portion of the letter is also devoted to the importance of attention to the "manner of breaking the circuit to obtain the maximum intensity."

Not the least important feature of this letter is the recommendation of local circuits for electro-magnetic telegraphs "where the distances are great." Recurring to the description of the spiral, the following conclusion was reached, and thus stated, (page 139:) "These last results show that the real maximum, as indicated by the shock, is given by the direct circuit through half the coil, with the lateral co-operation of the other half." The shocks were also obtained from the pure secondary circuit—that is, the circuit *exterior* to the primary or battery circuit. The shock is an indication of intensity, and *this is the first instance on record of the production of a shock in this way.*

It was by the employment of this powerful coil that Prof. Page first obtained the thermo-electric spark and shock, thus identifying thermo with Voltaic electricity. He first obtained the spark in August, 1836. (Sill's Journal, vol. 33, p. 118.) It was afterwards obtained by Italian philosophers,' Antinori and Linari, (L'Indicatore Sanese, No. 50, Dec. 13, 1836.)

The next induction coil we find to be that of Prof. Callan, of Maynooth College, Ireland, allusion to which has been before made. Prof. Callan's description of this coil is found in the London and Edinburgh Philosophical Magazine for December, 1836. This communication is dated August 23, 1836. Prof. Page's communication to Sill's Journal was dated May 12th, 1836, and its postscript June 8th, 1836. It did not appear in *that Journal* until the January No. for 1837; but, as we have shown above, through the maladroit accounts given by Mr. Peabody to Mr. Sturgeon and others, it was published in Sturgeon's Annals, vol. 1, No. 1, page 98. The whole passage giving this description has been already quoted, and also the fact stated that Mr. Peabody's relation of the discovery was given to Mr. Sturgeon and *others* in the latter part of July, 1836. Mr. Sturgeon remarks that Mr. Peabody was in company with Mr. Clarke, philosophical instrument-maker, at the time. *These dates and peculiar facts settle the question of priority in favor of Prof, Page, beyond controversy.* Prof. Callan's coil is described as consisting of two coils of copper wire, wound upon a bar of iron two feet long, and one inch in diameter. "These wires were in two lengths of 200 feet each, of the same size, and the end of the first coil and the beginning of the second were immersed into the same cup of mercury—the Voltaic current was passed through the first coil only, and the shock taken by making a communication with the beginning of the first coil, and with the end of the second." It was not stated whether one coil was exterior to the other, or whether they were side by side on different portions of the bar. The mode of obtaining the intensity current from the secondary current was *precisely a repetition* of that of Prof. Page's. No mention is made by Prof. Callan of a shock or a current from the purely secondary circuit.

In the Lond. and Edg. Phil. Magazine for October, 1857, (vol. 14, page 323,) we find a long article from Prof. Callan, asserting his claim as follows: "I was the first to discover the mode of making a coil by which a current of great intensity could be obtained from a small battery, and this was communicated to the Lond. and Eng. Phil. Magazine, Dec. 1836. Mr. Faraday was the first who developed the laws of electrical induction, but he did not discover the method of making a coil by which a current of very great intensity may be obtained from a very small battery. I sent a coil to Mr. Sturgeon, in the summer of 1837, and this was the first coil of great power ever seen outside the College of Maynooth. In April, 1837, I described in Sturgeon's Annals a circuit-breaker, which Mr. Backhoffner says, in one of his papers in Sturgeon's Annals, was the first contact-breaker ever made. Thus, before April, 1837, I had completed the coil as a machine for producing a regular supply of electricity. I also was the first to discover that the intensity of the induced current was increased by increasing the number of pairs of plates."

Prof. Henry, when experimenting with his flat spiral, which was only 96 feet long, found "little or no increase" from increasing the number of pairs of plates, but states that "it is probable that, if the length of the coil were increased in some proportion to the increase of intensity in the battery, an increased effort would still be produced." He also states as follows: "From other observations, I infer that the length of wire necessary to produce a maximum result varies with the intensity of the action of the battery, and also with its size." (Amer. Phil. Trans., 1835.) M. Masson, in 1835, used from six to twenty-four pairs of Wollaston battery with his coils of 1,000 feet and over in length, (Annales de Chemie, vol. 66, p. 9;) and Dr. Neef, in 1839, used a pile or a battery of intensity, (Pogg. Annals, vol. 36, p. 352,) to obtain shocks from the coil of wire on the electro-magnet. Professor Callan also stated that he was the "first to obtain shocks upon the completion of the primary circuit." Dr. Neef, in the above publication, speaks of obtaining the shocks upon completing the circuit. Both Professor Callan and Mr. Backhoffner must have been careless readers of Sturgeon's Annals, for Mr. Sturgeon describes a contact-breaker of his own in the October No. for 1836. Prof. Page described two contact-breakers in connection with his coil apparatus completed in the spring of 1836, published in

Sturgeon's Annals, vol. 1, page 292. M. Masson, in France, employed one in 1835, described in the report of Becquerel & Savary. at the Academy of Sciences, March 27, 1836, (Compte Rendus, 1837;) and Dr. Neef described one, in 1835, working without mercury, in connection with a coil around an electro-magnet. Both these latter will be described in another chapter. Mr. Callan put forth some excellent instructions concerning the making and insulation of coils, in the summer of 1837, but his coils were disproportioned and unwieldy. In the May No. of the Annals, page 304, he speaks of making a "small" magnet for the College, in which the iron bar was 2 feet long, 1⅜ inch thick. His advice, at this time, was to "coil the wire on a long and thick horse-shoe bar of iron, etc.;" and the coil sent to Mr. Sturgeon was on a horse-shoe electro-magnet. Prof. Callan carried his experiments and inquiries no further than to make large magnets and coils for producing shocks—one magnet was 13 feet long. As he has, however, been often mentioned by European writers as the first inventor of the induction-coil apparatus, we will recapitulate the historical evidences on the respective claims of Prof. Page and Prof. Callan. Prof. Page's communication to Silliman's Journal bears date May 12, 1836. Prof. Callan's communication to Phil. Magazine is dated August 23, 1836. The invention of Prof. Page was verbally communicated to the London Electricians about two weeks before the Bristol meeting of the British Association, held in August, 1836, which time, we suppose, must have been in the latter half of July, and a description of it published in October, 1836, in Sturgeon's Annals of Electricity and Magnetism, (vol. 1, No. 1, page 67.) Prof. Callan's experiment was published in the December No., 1836, of Lond. & Edin. Phil. Magazine. The communication of Prof. Page was published in full in Silliman's Journal for January, 1837. Prof. Page, therefore, was prior to Prof. Callan in his experiments and completion of his apparatus by more than three months, and two months prior by publication, and prior by the verbal announcement of his discovery in Europe by one month, to the date of Prof. Callan's communication. We, therefore, renew here the assertion made at the commencement of this investigation that—

The first galvanic induction apparatus, by which shocks and an intensity current were obtained from a secondary circuit, was made by Prof. Page;

The first induction apparatus, by which shocks were obtained from a purely secondary circuit exterior to the primary circuit, was made by Prof. Page;

The first induction apparatus, in which the battery current was caused to pass through only a portion of the circuit, while the shocks were taken from the whole circuit, was made by Prof. Page;

The first induction apparatus, in which the secondary circuit was longer, and many times longer than the primary circuit, was made by Prof. Page.

Prof. Page's coil was a flat spiral of copper ribbon, and had no magnetic core; and Prof. Callan's coils were made of wire, upon electro-magnets; but both these forms of coils were known before. The wire coil, with magnet inclosed, was many years old; and Dr. Ritchie introduced the flat spiral, or coil of copper ribbon, for magneto-electric induction, in 1833.—*Phil. Trans.*, 1833, *p.* 230. *The principle of action is the same in both.* The flat spiral exhibits but little increase of intensity from an inclosed magnet, while the wire coil shows it in a marked degree. Both these facts were noticed prior to Prof. Page's or Prof. Callan's experiments. The flat spiral was not so convenient nor suitable for carrying the induction to such a degree of intensity as the wire coil, and this was self-evident at the time Prof. Henry performed his experiments with the flat spiral, and had been clearly indicated and practiced in the immense lengths of wire used upon the armatures of the magneto-electric machines in the years 1833, 1834, and 1835, by Saxton and Clarke. Prof. Callan used in his coil 400 feet of wire, and from one to fourteen pairs of plates. M. Masson, in 1835, used over a thousand feet of silk covered wire for his magnetic coil, and from six to twenty-four pairs of Wollaston plates. Dr. Neef does not mention the amount of wire upon his magnet in 1835, but, as he used a battery of intensity, and obtained severe shocks, he *must* have used a very long wire. In view of these facts, we cannot see, therefore, that any argument can be made in favor of a discovery or new invention on the part of Prof. Callan, except his own peculiar form of mechanical circuit-breaker. He merely repeated experiments made before, by Prof. Page and others. Subsequently, as we shall see, he performed them upon a larger scale than had been done before.

It was well said by Mr. Sturgeon that the "experiments by Mr. Page are very important." They laid the foundation for the construction of the whole of that class of instruments and experiments adopted in the pursuit of the subject of intensity currents by induction in secondary circuits, which has progressed to such an extent that, beginning with the feeble charge of a Leyden jar by Prof. Page's coil, we have now coils giving sparks fifteen inches to two feet in length. The same principle of construction is found in all the induction coils for medical purposes made since 1836.

Having thus established the claim of Prof. Page to the first induction apparatus for obtaining shocks and intensity currents from a secondary circuit, by a full and impartial historical review, and, as we think, the most conclusive proofs, we shall proceed to notice some of the subsequent productions by others, and show how quickly the impulse was given to European electricians to follow up this interesting and important investigation. Mr. Sturgeon, with the description of Page's apparatus before him, did not at first appreciate its principle, as he afterwards acknowledged. In the self-same article, he was describing an attempt to produce currents of intensity by the use of two coils which were not in such a relation to each other as to be subject to inductive action. (Sturgeon's Annals, Oct. 1836, page 67, et seq.) Eight months afterwards, in commenting upon the "importance of Mr. Page's experiments," a full description of which he had just given, he acknowledges the cause of his failure in former experiments, and remarks, "I now obtain shocks from secondaries alone." These remarks from Mr. Sturgeon, who, as the editor of the only journal in existence at that time, and, moreover, as a distinguished electrician himself, must have had the means of thorough information upon what had been accomplished up to that time, afford incidentally the strongest corroborative evidence of Prof. Page's claim to priority.

In the April No. of Sturgeon's Annals for 1837, Prof. Callan communicated a brief article describing a complicated mechanical contrivance for breaking the primary circuit with rapidity, so as to obtain shocks from the electro-magnet. In the course of this article, he speaks of the thick wire for the primary, and thin wire for the secondary circuit, but does not give the length of either. The communication was without date. Thin or fine wire is purely a relative expression, but here is meant a wire for the secondary smaller than that used for the primary circuit. We are unable to trace accurately the history of the introduction of fine wires for intensity circuits. The wire in common use for conductors and coils, from the commencement of experiments in electro-magnetism, was bell wire, or No. 16, which is about $\frac{1}{16}$ of an inch thick; and unless authors specify the diameters of wires, we take it for granted that copper wire means bell wire size. Mr. Clarke, the author of one of the principal forms of magneto-electric machines, says: "Having, in November, 1834, tried the effects produced by coils varying in diameter, I found that the thick copper bell wire gave brilliant sparks, but no perceptible shock, whilst, on the contrary, very fine wire gave powerful shocks, but very indifferent sparks. I took advantage of my discovery, and furnished my machines with two armatures—one of thick wire, and one of fine wire." (Lond. and Edin. Phil. Magazine for October, 1836.) So far as we are able to learn, Prof. Callan was the first to adopt the fine wire for the secondary coil, in combination with a coarser primary wire on the electro-magnet.

In Silliman's Journal for 1837, vol. 32, No. 2, Prof. Page, under date of *April* 19, 1837, stated that he had increased the spiral to 320 feet, and that with 12 pairs of plates, (Daniell's battery,) a current of sufficient intensity was obtained in the induced or secondary circuit as to pass before contact between points of charcoal. This was obtained with an automatic circuit-breaker, made of a Ritchie revolving magnet, the mercury being a cylindrical glass cell and covered with water. The high intensity of the secondary in this case was due to the mode of breaking the circuit. Three other kinds of automatic circuit breakers were described in this article. *In the July No. of Sturgeon's Annals for 1837, (vol. 1, page 376,) Prof. Callan, under date of June 14, 1837, describes a newly constructed electro-magnet of great size, the bar of iron being 13 feet long and 2½ inches in diameter, covered with a primary coil of large wire 490 feet long, and a secondary coil of fine wire 10,000 feet long. The shock was sufficiently intense to kill a fowl. Near the close of this article, he alludes to an observation made about "four months before, with a thick and thin wire coil;" but in a subsequent communication, dated three months after, and published in the October No. of Sturgeon's Annals, (vol. 1, No. 6, page 493,) he describes the same observation as made about "four months before;" and this latter is undoubtedly the correct date, and would carry the date of his adoption of the fine wire coil to about the 11th of May, 1837. Many of Prof. Callan's statements are loosely made, and the period of "about four months" seems to have been a favorite mode of antedating, as it occurs three times in these last two communications. Another very singular anachronism is found in connection with his communication just referred to in the July No. of Sturgeon's Annals. It is dated June 14th, 1836, instead of 1837. This date may have misled those who did not look beyond the communication itself. Under such a date, however, the facts communicated would be utterly irreconcilable with his former communications, especially that published in the December No. of the Lond. and Edin. Phil. Magazine, which we have before cited, and with his claims set up in the second volume of Sturgeon's Annals, page 318. The mistake of the date is, however, clearly proved by a promise made in the last clause of the communication taken in connection with a reference to this promise in the ensuing October No. of the Annals, (page 493.) The promise was to "furnish for the October No. a description of an electro-magnetic engine he was then building." In the October No., 1837, he says, under date of September 11, 1837, "the engine I was building in June, mentioned in the July No. of the Annals, was tried before it was completed, and found to contain two defects. It will be ready for work the end of this month, (September, 1837,) or the beginning of next." This establishes the fact that the date should have been 1837, instead of 1836, beyond all controversy. If it were a genuine date, it might well bring the claim for Prof. Callan to the induction secondary for shocks to a par, or even beyond that of Prof. Page; for, if he made this communication under date of June 14, 1836, and an "observation"

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* Owing to some erroneous antedating of Prof. Callan's and other communications, we introduce them here in advance of their chronological position.

"about four months before," with a short coil of thick wire for the primary circuit, and a long coil of thin wire for the secondary, that observation would have been made at least two months before the date of Prof. Page's first communication. We are thus particular in exposing this error, as it may have given rise to a false impression in regard to Prof. Callan's claim.

Another case of equivocal antedating is found in Noad's Lectures on Electricity, published in London in 1854. (Noad's Lectures, page 405.) The author says, "on repeating the experiments of Faraday on induction, soon after their publication, he was induced to try the effects of strong and weak currents on a flat coil of considerable breadth." He then proceeds to describe a flat spiral, of the same length and size as that made by Professor Page, and the whole construction, even to the use of "*list*" for insulation, presents a fac-simile of Professor Page's spiral, and the results obtained were very similar. Faraday's experiments were published in the latter part of 1834 and beginning of 1835, and the language of Mr. Noad would leave the impression that he availed himself promptly of the discoveries of Faraday to carry out his own views. In his Manual of Electricity, subsequently published, (Part 2, page 704,) he makes the language a little stronger, as follows: "The following experiments were made by the author *shortly after* the publication of Faraday's researches." The statement is too vague for admission as historical evidence. Fortunately, however, we can so far fix upon the date of these experiments as to show that "soon after" and "shortly after" could not have been less than *three years* after. In experiment 13, Mr. Noad says: "By employing Callans' coil (an arrangement to be described presently) powerful shocks were obtained from the secondary current." As Professor Callan's coil was not known until October, 1837, (*Sturgeon's Annals, October* 1837) the experiment was not made, of course, until after that time. In the Manual, (Part 2, page 707,) Professor Callan's name is dropped, and the language used is, "by employing a coil apparatus." This does not vary the case much, for there was no coil apparatus known before Professor Callan's, except Professor Page's. Mr. Noad also speaks of using Ritchie's magnet for a circuit-breaker in the same experiment, and also a revolving wheel. This makes the coincidence with the Page coil still more striking, as a revolving wheel was used with it in 1836, and the Ritchie magnet as an automatic circuit breaker in April 1837. (Sill's Journal, vol. 32, page 355.) Mr. Noad does not appear to have made known his experiments until some years after their alleged performance.

In the year 1837, especially during the latter part, a lively interest was manifested in this subject in England, and quite a number of forms of induction apparatus by different authors were published in Sturgeon's Annals. Mr. Barker, under date of December 12, 1836, communicates to Sturgeon's Annals (Vol. 1, No. 2, page 159) for January 1837, that he was making a helix of 2,000 feet of wire around a glass tube three feet long, into which a bar of iron was to be inserted. He also sends a figure without a description of a mechanical circuit-breaker, the same in principle as the spur wheel of Professor Page. No report of the operation of this coil was published.

In the April number of Sturgeon's Annals, page 193, Mr. Sturgeon described some experiments with a coil of wire 300 feet long and 1-20 of an inch thick, covered with silk. It was wound upon a wooden reel or bobbin, having a central opening for the admission of an iron bar about two inches diameter, and the space between the cheeks of the reel two inches, and various experiments are detailed with this coil and others of less length. In the course of these experiments he made the interesting discovery that the coil 300 feet long gave stronger shocks on a straight bar of iron than upon a bent or horse-shoe form, and the still more remarkable and interesting discovery that the same coil, when occupying a short space over the middle of the bar of iron, gave a much stronger shock than when wound over the whole length of the bar, notwithstanding the latter mode of winding produced the strongest magnet. These discoveries have since been verified by others. No attempt was made with a secondary circuit, the coils being primaries only.

In the May No. (1837) of Sturgeon's Annals, vol. 1, page 300, Prof. Callan describes an electro-magnet of great size—13 feet long. 2½ inches diameter—covered with thick and thin wires—the thin wires being of iron. He also describes a powerful magnetic coil, with 50 feet of No. 12 wire for primary, and 1,300 feet of No. 40 iron wire for secondary, coil. With a single pair of 7-inch plates this gave powerful shocks. The thin wires in both the above cases were soldered to the primary wire.

In the July No. of Sturgeon's Annals, page 376, Prof. Callan describes a large coil. The magnetic bar was 13 feet long and 2½ inches diameter. The primary wire, ⅛ of an inch in diameter, was in seven lengths, each 70 feet long. The secondary wire was $\frac{1}{40}$ of an inch in diameter and 10,000 feet long. This has been before described. The primary and secondary wire were connected together, and no observations made beyond those of sparks and shocks. Up to this time all the coils made were either primaries alone, or else the secondaries were connected with the primaries.

In the October No. of the Annals (page 470) is published a paper read by Mr. Sturgeon, August 5, 1837, before the London Electrical Society. He describes a coil, with a primary circuit of thick bell wire, two hundred and sixty feet long, and the thin wire for the secondary 1,300 feet long. These were wound on a hollow reel of wood—the distance between the cheeks of the reel being *two inches.* This form was not the best for displaying magnetic reaction, but was much more convenient than the coils of Prof. Callan, which were wound permanently upon very long and large bars of soft iron. Mr. Sturgeon's coil was fitted to a base-board, and provided with a mechanical circuit-breaker, worked by a multiplying wheel, band, and pulley. With this apparatus Mr. Sturgeon discovered that a bundle of iron wires inserted in the coil gave brighter sparks and much heavier shocks than the bar of solid iron. He also tried sheet-iron rolled up, and plates of iron, with similar increased effects. In the course of this paper Mr. Sturgeon states that Mr. Payne, of Adelaide Gallery, and Mr. Bachhoffner, had also tried the effect of the bundle of wires, but does not furnish the dates of discovery, and leaves the question of priority unsettled. About six months after, Mr. Bachhoffner claims that he first introduced the bundle of wires.—(*Sturgeon's Annals, vol.* 2, *p.* 213.) No attempts were made to test the intensity of the secondary by electrostatic tests. Mr. Sturgeon recommended his apparatus for medical application, and states that several had been ordered by medical men. It is worthy of note, that four months after this announcement Prof. Page, without knowing what had been done in Europe, made precisely the same discovery in regard to the bundle of wires, the roll of sheet-iron, and the iron plates. With Prof. Page the discovery was the result of a process of purely inductive reasoning, as related by him in Silliman's Journal, (vol. 34, No. 1, page 167, for July, 1838,) and he promptly applied it to the induction coil, together with his spark-arresting circuit-breaker, to develop electrostatic effects by secondary currents of the highest intensity, as we shall show in the chapter on circuit-breakers, and elsewhere.

Some time in September, 1837, Prof. M'Gauley, of Dublin, exhibited at the meeting of the British Association, at

Liverpool, an electro-magnetic coil apparatus. which, though very awkwardly constructed, yet embraced one very important and ingenious feature, viz: an automatic circuit-breaker, which was, in one particular, the type of most of the automatic circuit-breakers now in use. It, however, was deficient in having no adjustment to vary its force. This will be explained in the chapter on circuit-breakers. Suffice it to remark, it was the *first* invented in Europe. This coil consisted of two large wires—No. 13—580 feet long, each wound upon a bar of iron 2 feet long and ¾ of an inch in diameter. The coils were *interwound* like Faraday's, and not superposed as in Callan's coils and others. The description was not published till 1838.—(*Pro. Brit. Association, vol.* 7, *page* 25. *Proceedings before Lectures.*)

In the October No. of the Annals, page 493, Prof. Callan, after describing an attempt to increase the intensity of the secondary, by employing a series of coils upon separate electro-magnets, and uniting them so as to get the combined power, remarks, that, for the purpose of getting "increased intensity in this way, care must be taken not to solder the thin to the thick wires of the magnet, and to leave both ends of the thin wires projecting." To this remark Mr. Sturgeon adds a note to the effect that he had used in his lectures the thick and thin wires, each on separate reels, the diameter of the thin wire reel being such that the thick wire reel could be inserted within it at pleasure. Mr. Sturgeon gives no date to his time of using this arrangement, while Prof. Callan's communication is dated September 11, 1837. It is obvious that Mr. Sturgeon's plan insures complete insulation of the secondary and primary coils, although this does not seem to have been his purpose; and unless the hollow axle of his reel or bobbin for the secondary was made very thin, there must have been considerable loss on account of its remoteness from the primary. Prof. Callan seems, however, to have been fully aware of the importance of attention to insulation some time previous to this. In the May No. (1837) of the Annals Elec. and Mag., page 297, he remarks, as follows: "*Sixthly*, the intensity of the electric current excited in the magnetic helix depends on the insulation of each coil from all the other coils. However great the magnetic power may be, however long or fine the wire, however small its distance from the iron, and however perfect the coiling, the intensity of the electric current will be but trifling if the insulation be bad. When high intensity is sought for, the covering of the wire will not be sufficient to insulate each coil from all the other coils. A coat of sealing-wax varnish or some other non-conducting cement will be necessary." In this same communication he describes his secondary as connected by soldering one end to the primary; therefore, although the layers, or coils, as he terms them, were carefully insulated from each other, the primary and secondary circuits were not *separable*, as in Sturgeon's apparatus. This is an important point of this subject, as will appear hereafter in the chapter on the Electrostatic Powers of the Coil. It is remarkable that, with these advantages of insulation and separation of the coils, no attempt whatever was made to indicate an intensity higher than that for producing the shock.

In the October No. of the Annals, (1837,) Mr. Bachhoffner describes his experiments with one of Sturgeon's compound helices and a new mechanical circuit-breaker. In this article he announces his discovery, that "by inserting a bundle of iron wires in the helix, in place of a solid bar, the power of the current is increased two-fold."

In the same No. is also a description of experiments, with a powerful coil, by Mr. Clarke, instrument-maker, of London, in which he states that, by drawing the "conductor over a steel file placed in the circuit, a succession of violent shocks will be received, and that this arrangement answers very well for illustrating the effects of secondary currents giving shocks." For "applying the shocks medicinally, however, he introduces a spur wheel revolving in mercury." The editor, Mr. Sturgeon, in a note, administers a rebuke to Mr. Clarke for not giving credit where it was due, and states that the same thing was published in a "prior No. of the Journal, and that the original employment of the spur wheel and mercury for this purpose was by Mr. Page." He might have added also the original use of the "*file or rasp*" for this purpose, (see May No., 1837, page 293,) as it is described in the same article.

In the January No. of the Lond. and Edin. Phil. Magazine, 1838, (vol. 12, page 18,) Dr. Golding Bird describes, in a letter dated November 2, 1837, experiments with a coil consisting of a primary of 60 feet of wire 1-12 inch thick, wound on a reel with hollow axis, three inches in length, and covered with cotton thread, for the purpose of insulation, and over this a secondary insulated wire 1-80 inch thick and 1,300 feet long, also covered with cotton. Powerful shocks and electrolytic effects were obtained by an automatic or magnetic contact-breaker, which he extols very highly, in place of the mechanical circuit breakers. At the conclusion of his letter he states that, when he invented this it was new to him, but that on the arrival of the October No. of Silliman's Journal for 1837 he found that he had been anticipated, and the merit "of originality belonged to Dr. Page." It appears that comparatively little interest was manifested in France, Germany, or Italy, in this subject during the year 1838.

In the March number of Sturgeon's Annals for 1838, page 204, Rev. Mr. Nesbitt describes a coil apparatus similar to Sturgeon's, or rather to Bachhoffners, and also a new circuit-breaker, which was not so noisy as the ratchet wheel, the spaces between the teeth being filled up with wood.

Immediately following is an article from Mr. Bachhoffner, in which he gives the preference to his ratchet wheel circuit-breaker over the automatic circuit-breaker of Dr. Bird, for the reason that in the latter the "poles of the magnets require nice adjustment, and stop the action if at all displaced."

In the April number of the Annals for 1838, page 318, Professor Callan makes the following assertion: "I believe I was the first who used the coils for shocks." By this he means, of course, a primary and a secondary coil. In this we have already seen that he was anticipated by Professor Page.

The next coil apparatus of record is that of Professor Page, communicated under date of June 2d, 1838, for Silliman's Journal, and published in October following. In this machine, called the Magneto-Electric Multiplier, the primary and secondary circuits were insulated from, and independent of, each other, and wound upon a bundle of iron wires, bent into a horse-shoe or U form. The circuit-breaker was so arranged upon a shaft bearing an armature that the circuit might be broken at the instant the armature required the maximum of mechanical force to cause it to recede from the poles of the magnet, and thus effect the more sudden neutralization of the magnetic forces, and augment the intensity of the secondary. It is emphatically said of this coil, that the "*secondary is insulated from, and entirely independent of, the primary.*" We have already seen that Professor Callan recommended the separation of the two circuits, but only in case a number of magnets were to be united for the purpose of getting the sum of their secondaries. That Mr. Sturgeon also used primaries and secondaries, coiled on separate reels or bobbins, without reference to any increase of intensity, but merely for showing their powers when separated. A convenient arrangement for such purpose, but not so economical of space (an important element) when they were put together, as when the coils were wound one upon another, with a thin insulating stratum between. The only other coil apparatus, where the secondary was superposed, presenting this feature, was that of Dr. Golding Bird, already described. In this the coils were superposed, but not connected. There was no insulation, however, except the ordinary cotton-winding on the wire, which experience had already shown to be inadequate for the insulation of high intensity. The developments of this coil of Professor Page were novel and striking, and it is but just to say that it was the *first published* organized induction apparatus in which the secondary and primary coils were *insulated* and *independent*, and at the same time overlaid—that is, the secondary wound upon the primary, with suitable insulation between. We say the "first published," because the next coil of Professor Page, called the "Compound-Magnet and Electrotome," though completed in April, 1838, as we shall see, was not published till November, 1838. This had the same construction. The following striking results were obtained: The secondary current was so intense that it was "felt through the table and floor. It "charged a Leyden jar," and when a "single thermo-electric pair of bismuth and antimony heated and cooled was connected with the primary, a shock was received from the secondary which was felt as far as the wrist." It also gave shocks, without breaking the circuit, by the mere movement of the armature. De La Rive, in his celebrated work on Electricity, published in 1853, (vol. 3, page 503.) remarks, that "one of the induction machines most anciently employed in the hospitals of Paris, is that of M. Breton Brothers, (Fig. 431,) in which following the system devised by Mr. Page, etc., etc." It was merely a repetition of the magneto-electric multiplier just described. The value of this invention was extensively recognized among the physicists of Europe, and was employed by them as an instrument of research superior to all others of its class. Becquerel informs us that, in studying the effects of induction produced by the movements of different metals, M. Brequet, and also M. Berdet, both adopted "*la machine de Page.*" (*Traité d'Electricité*, vol. 3, pp. 269, 264.)

The next published account of induction apparatus is also one of Prof. Page's. The first description of this improvement is in a work published by Daniel Davis, Jr., of Boston, in November, 1838. The little work of 72 pages, though entitled a "Descriptive Catalogue," is essentially a treatise upon the subject of electro-magnetism and magnetic electricity. For the sake of distinction, we shall call it Davis' first manual. Three pages and a half are devoted to the description and explanation of this new induction coil apparatus. It embraced two important and distinctive features of construction. (See Fig. 2.) One the automatic device for breaking the circuit, which is effected by the attraction of a small piece of iron, G, by one end of the magnet, the iron being attached to a wire E, suspended over a glass mercury cup M, in such manner that the motion of the iron lifts the wire from the mercury and breaks the circuit. The distance between the iron and magnet is easily adjusted, as also the force with which it is held, and pulled back by means of the adjustable weight F, so that the length and rapidity of the vibration may be regulated at pleasure. It was the first circuit-breaker in which the resistance was adjustable, without altering the attractive force. It is not intended in this *resumé* to give a description in full detail of the various kinds of apparatus referred to; for this, the reader must have recourse to the original communications, references to which have been carefully given. The following comprehensive quotation will suffice:

"PAGE'S COMPOUND MAGNET AND ELECTROTOME."

"This instrument consists of a horizontal compound electro-magnet, (meaning by this a wire magnet,) enclosed in two *separate helices, entirely insulated from each other*, (one the inner, for the electric current from the battery, and the other for the induced current,) with a vibrating apparatus attached above, by which the battery current is interrupted and renewed alternately in rapid succession." The other important feature of operation is what we term the spark-arresting circuit breaker. By covering the mercury in the glass cup with "water, oil, naptha, alcohol," or other poor conducting liquid, when the wire is lifted from the mercury the separation spark of the primary is presented to a great extent, and the whole reactive force of the magnetism is suddenly exerted upon the secondary coil, and thus augments the intensity of the current. It is stated that "water, oil, or naptha, upon the surface of the mercury, diminishes the brilliancy of the sparks, but increases the intensity of the shocks." "Prepared charcoal points, attached to the extremities of the fine wire, and brought almost in contact, produce a beautiful light. The extremities of the fine wire will also decompose water, deflect the galvanometer needle, and charge the Leyden jar."

Prof. Page, who furnished the material for this description, asserts that, instead of deflecting the galvanometer needle, it should have read, "deflect the gold leaves of the electroscope." We have proceeded in this work upon the principle that nothing should be assumed unless directly or indirectly substantiated by the record of facts. It was, of course, in such a connection entirely superflous to state that the secondary current deflected the galvanometer, and in the next edition of his work, when Mr. Davis explains how the decomposition of water was accomplished by this coil and circuit-breaker, and other results produced, he states that "it diverged the gold leaves of the electroscope without a condenser." (Edition of 1842, pp. 183, 184.) This point will be more fully investigated under the chapter on the Electrostatic Powers of the Coil.

We may form some idea of the importance attached to this induction apparatus, from the fact that, in a supplementary letter-sheet catalogue issued the next year, Mr. Davis advertises three different sizes of the same. One with 3,000 feet of fine wire, one with 2,000 feet, and one with 1,000 feet, the prices being $20, $15, and $10. He also described an interesting modification of his own invention of the spark arresting circuit-breaker, causing the wire to vibrate in the mercury cup by means of clock work. (See Fig. 3.) In connection with this, the coils were placed in a vertical position. There was also attached to the base-board the *steel rasp*, the original circuit-breaker adopted by Prof. Page in 1836. (Sill's Journal, vol. 31, p. 140.) In describing the working of this identical apparatus in the edition of Davis' Manual of Magnetism, published in August, 1842, it is stated that " water or oil, poured on the surface of the mercury, diminishes the sparks, but increases the shocks. A beautiful light is produced between charcoal points almost* in contact. Water may be decomposed by fine platinum wires, having their points guarded by glass tubes. The extremities of the wires are luminous—one constantly and brightly, and one feebly and intermittingly. Rapid discharges are heard in the water, producing sharp ticking sounds, audible at the distance of 80 or 100 feet. A Leyden jar is charged so that a rapid succession of shocks may be received from it. A gold leaf electroscope is diverged without the aid of a condenser." It should be borne in mind that this is a description of the operation of Prof. Page's apparatus, on sale, and fully described, and advertised four years before, with the exception of the clock-work, which, of course, did not affect the results, and is quite a chapter on the Electrostatic Powers of the Coil.

It is pertinent to the object of this investigation to remark, that upon a review of all the recorded experiments and observations made with induction coils, we find that no attempt had thus far been made to produce

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***Almost in contact is, of course, not in contact.**

electrostatic effects by the secondary current by any author except Prof. Page. Experiments had been made long before with a view to establish the identity of galvanic and frictional electricity, and the current from the magneto-electric machine had been made to produce electrostatic effects, but the current of Volta-electric induction had been let alone in this respect by all experimenters, from Faraday down to the latest of our record, except by Prof. Page. So steadily was this important point kept in view by him, that in each of the five* publications made by him, from 1836 to 1839, on induction coils and secondary currents, some allusion is made or some result obtained to illustrate what is now-a-days generally termed the conversion of dynamic into static electricity. It is also worthy of remark, that, notwithstanding the early publication (Silliman's Journal, vol. 31, No. 1, pp. 139, 140) of the intensity results obtained by breaking the circuit under non-conducting liquids, and their republication in Europe in Sturgeon's Annals, and elsewhere, no one seems to have repeated the experiments until their re-discovery by Poggendorff, in Germany, in 1854, and afterwards by Foucault, in France. Prof. Page laid *particular stress* upon this point in his rationale in 1838.—(*Sill., vol.* 34, *No.* 1, *p.* 166, *and vol.* 35, *No.* 2, *p.* 256.) Du Moncel and Becquerel both take the ground that the electrostatic character of the secondary was settled by the experiments of Masson and Brequet in 1842. As will be hereafter seen, their results were, if not equivocal, at least very far behind those obtained by Prof. Page several years before.

A description, with an engraving, of the compound magnet and electrotome, was communicated by Prof. Page to Silliman's Journal under date of November 13, 1838, and published in vol. 35, No. 2, p. 258, July, 1839. The description is much more brief than that previously published in Davis' work, and is prefaced with the statement that the apparatus was completed in April, 1838.

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* Silliman's Journal, vol. 31, No. 1, pp. 139, 140; vol. 32, No. 2, p. 355; vol. 24, No. 1, p. 166; vol. 24, No. 2, p. 372; vol. 35, No. 2, pp. 256, 257; also, Davis' Work above-mentioned, p. 48.

In the July No. of Silliman's Journal for 1838, vol. 34, No. 1, page 166, Prof. Page describes a series of very striking results from the secondary current of a new magneto-electric machine. It is true no secondary wire circuit was used here, but the current was a pure secondary, and its great power due to the use of the *spark arresting circuit breaker.* The alternating currents of the armatures were converted by an original contrivance into one uniform current, and this current, being led by two electrodes to the table or top board of the instrument, was there broken by a vibrating circuit-breaker, so regulated and adjustable that the circuit could be broken at any desired position of the revolving armatures. It operated in the same manner as that of the compound magnet and electrotome, by lifting a wire from a glass cup partly filled with mercury, the surface of which was to be covered with "pure water, naptha, oil," "or other non-conducting liquid." "Alcohol, ether, etc., are also mentioned (page 165) as used in the cup. Among the remarkable results noticed are—

First. "When one of the electrodes was suddenly withdrawn from the other, a bright spark was obtained half an inch in length."

Second. When the "lever trip" (the spark-arresting circuit-breaker) "was worked, the secondary was seen to play across the space between the segments of the pole changers." This space was about $\frac{3}{16}$ of an inch, and the spark here was projected without contact. It was, however, undoubtedly aided by the abraded atoms of silver.

Third. "The shock from the direct current was uncomfortable with dry hands; but, when the secondary was used, it was painful to touch the poles even with the fingers."

Fourth. "It caused the gold leaves of the electroscope to diverge strongly without the aid of a Leyden jar, or extended insulated metallic surfaces."

Fifth. "It charged a Leyden jar at every touch."

Sixth. "A charcoal point on the knob of the jar affords a bright light at every touch."

Professor Page then proceeds to give the rationale of the "great increase of the secondary" by the use of the spark-arresting circuit-breaker. An engraving is also given of a peculiar diffuse spark spreading out over the surface of bright metal to the extent of an inch. We have not seen a notice of this phenomenon by any other author. In the Saxton and Clarke magneto-electric machines which preceded this, it required two sets of armatures—one with coarse and one with fine wire coil—to exhibit the currents of quantity and intensity; but in this machine the decomposing power was exhibited by the direct current, and the intensity and physiological effects were produced by the peculiar circuit-breaker. The first practical magneto-electric machine was made by Mr. Saxton, of Philadelphia, and that just described was the first by which the way was opened for unlimited increase of the magneto-electric current, by increasing the number of magnets and armatures, instead of increasing the size of the magnet and coils to which, of course, there would have soon been found a limit. Alluding to this machine, in November, 1838, (Sill's Journal, vol. 35, page 252.) Professor Page promised to make one on the same plan to "rival the largest galvanic battery in existence," and explains the mode of obtaining a constant stream of light by disposing of the armatures, so that while one was giving the diminishing current, the other would give the increasing current. The enlargement here contemplated was afterwards carried out by Mr. Wheatstone. (See Daniell's Introduction to Chem. Philosophy, page 588; also, Du Moncel's Traité d'Electricité, page 361, vol. 1.)

The next published induction apparatus of any note was that of Mr. Gassiot, of England. (Phil. Trans., 1840, p. 183. Received October 11th; read December 19, 1839.) More than a year after these experiments of Professor Page, Mr. Gassiot undertook to verify what was called the striking distance—that is, the distance through which the secondary current would pass before the contact; or, in other words, to test the electrostatic powers of the induced current. He employed an accurate micrometer screw instrument, called a "Micrometer Electrometer," capable of measuring 1-5,000 of an inch. He found that the current from a magneto-electric machine would not break through this space. The machine must have been far inferior in power to that of Professor Page just described. He then adopted the magneto-electric multiplier of Professor Page, which had been figured and fully described in Sturgeon's Annals, March 1839. page 488, and already noticed in Sill's Journal, Octotober, 1838, page 371, but with two remarkable deficiencies. First, he paid no particular attention to insulation, relying upon simply cotton covering of the wire; and second, instead of using mechanical force to break the circuit at the point where the secondary would have been at its maximum, he allowed the armature to break the circuit by independent motion, and thus lost a great part of the real value of the instrument. And we might add, also, that, although he employed a mercurial cup in his experiments, he did not apply the spark-arresting principle to contribute to the power of his secondary. He, however, employed powerful batteries, twenty cells, Daniell's battery, and obtained important results. "Between platinum points" he obtained from the secondary circuit "*minute but brilliant sparks* at every rupture of the primary circuit through 1-100 of an inch."

"When charcoal points were approximated to 1-500 of an inch, the sparks appeared in quick succession, having the appearance of a continued but glimmering flame."

"Thin paper, introduced between the platinum or charcoal terminals, was perforated at every revolution of the bar."

"A Leyden jar was charged sufficient to deflect the leaves of gold leaf electroscope."

"A spark could be taken by the knuckle, or a metallic ball from either terminal of the secondary."

The most powerful galvanic batteries employed could not project a spark through 1-5,000 inch. It, however, was soon after discovered by Mr. Crosse that a water battery of 1,626 pairs projected sparks; and about four years after M. Gassiot obtained them with a water battery of 3,520 pairs.

In Silliman's Journal, (July, 1840,) is found a lengthy account of the experiments of Professor Henry upon induction, communicated to the American Philosophical Society November 2d, 1838, in which he discovered the different orders of currents produced by induced currents. The paper is full of scientific interest, but nothing novel is presented in the construction of apparatus.

The next coil to be noticed is one of extraordinary size, but only mentioned in a casual manner. Mr. Gassiot, under date of 17th September, 1841, reports to the Lond. Elec. Society that he tried the projected spark with a powerful battery and his large coil. The battery is not described. The coil weighed 86 lbs., and the secondary coil was made of No. 30 copper wire of the immense length of "*twelve miles*." The wire was covered with cotton, and insulated with shellac varnish. With this arrangement he obtained a spark before contact. The length of the spark is not given. He states that in the flame of a spirit lamp he obtained a spark three quarters of an inch in length. This report did not appear in print till 1843. (Proc. Lond. Elec. Soc., page 119, 1843.)

In the year 1842, according to Becquerel, or according to Du Moncel, about or towards the year 1842, ("vers l'année,") M. M. Masson and Breguet also undertook to verify the identity of dynamic and static electricity by the operations of the secondary current. Their memoir is found in the Annales de Chimie, vol. 4, 1842, page 129. It is there stated that the memoir was presented to the Academy of Sciences 23d August, 1841. They employed powerful batteries, forty pairs Daniell's, and a coil of wire 1,300 metres in length, and two and a half millimetres in diameter, divided into two equal lengths, which were wound in juxtaposition into a bobbin or coil of such proportions that the central or core opening was over 6 inches in diameter. The iron core adapted to this opening was so large as to actually retard the secondary current, and they were therefore deprived of the aid of magnetic reaction. Their powerful battery, however, compensated and supplied the intensity needed. They employed a mechanical circuit-breaker, and charged a condenser and a Leyden jar. They failed to obtain any spark through the air from the secondary current, but succeeded in passing it through a vacuum when the wires were about ¾ inch apart. We think their results equivocal in some respects, for reasons to be given in another chapter. Du Moncel, Becquerel, Noad, and other writers, agree in stating that they employed but one coil; that is, their secondary current was that of the primary circuit. This current the French, and most writers, call the "extra current," while that of the secondary circuit is called the induced current. As we interpret their memoir, they claimed to have produced the same results with the induced circuits, although only by incidental mention.

In Davis' Manual of Magnetism, edition of August, 1842, are described in detail several powerful coils, which had been before described in his first edition of November, 1838, and in a supplementary catalogue of 1839. The description is more full as to the results than had been before given, though all are the identical Page coils of 1836–9. That figured and described on page 181 has the mercurial spark-arresting circuit-breaker of Prof. Page worked by clock-work, which is an advantage in some respects, though not quite so convenient and cheap as the automatic movement. (See Fig. 3.) The clock-work application was the invention of Mr. Davis, and described by him in his catalogue of 1839. Surprising *electrostatic* results are ascribed to this instrument, (page 184, sec. 325,) which we have before cited, and shall hereafter more particularly examine. On page 186 is figured one of these powerful coils, with one of Page's automatic circuit-breakers attached. (See Fig. 4.) This circuit-breaker was described in Sill's Journal, vol. 35, No. 2, page 262, as "invented in February, 1838."

Mr. Noad, in his Manual, edition of 1857, page 727, immediately after describing the experiments of Masson and Breguet, in 1842, says: "About the same time Mr. Hearder, of Plymouth, England, constructed a powerful coil, for which he obtained, in September, 1846, the silver medal of the Royal Polytechnic Society of Cornwall." With this coil he obtained strong sparks in air, Leyden jars were charged, and a striking distance obtained of several inches through rarified air. This seems to be an anachronism, as in his recent work, entitled the *Inductorium*, published in 1866, Mr. Noad describes the same coil of Mr. Hearder, (page 35,) as "made shortly after the announcement of Ruhmkorff's coil." In giving the history of induction, he makes no mention of any coil or developments as occurring between the experiments of Masson and Breguet and Ruhmkorff's first attempt in 1851. In fact, very little of interest transpired on the subject of induction coils from 1842 until 1850. During that period, however, very large coils, on the plan of Prof. Page's coils, were made in the United States by instrument-makers, which gave long sparks and lighted vacuum tubes of considerable length. Some of these secondary coils, made prior to 1846, were several miles in length, and furnished sparks from one-tenth to one half of an inch in length in the air. The only printed account of these coils is to be found in the Memorial of Prof. Page, laid before the 39th Congress, 1866. The descriptions are embodied in affidavits of N. B. Chamberlain, of Boston, and Robert Grant, well known as instrument-makers in this country for many years. This subject will be resumed in another chapter.

In 1850 some remarkable experiments with induction coils were made by Professor Page, and published in Silliman's Journal. Three reports on the subject may be found in vol. 10, No. 80, November, 1850, page 349; vol. 11, No. 31, January, 1851, page 88; and vol. 11, No. 32, March, 1851, page 191. The coils and magnetic bars were on a grand scale, and by far the most powerful magnets ever produced. One of the helices raised within its central opening "*a bar of iron one thousand and forty pounds in weight, vibrating in the air without visible support.*" These helices have been described elsewhere as made of square wire $\frac{1}{4}$ inch thick, of very pure copper, and the battery used, from fifty to one hundred pairs Groves, with platinum plates one hundred square inches immersed. Very interesting experiments were performed, showing that the time required to raise the current to its maximum in the coils varied, according to circumstances, from $\frac{1}{6}$ of a second to two seconds, and that the subsidence of the current was in the same time. Coils were closed after the battery current had been withdrawn, and afterwards opened within a half second, and a current still found to be flowing. The time required was much less when no magnetic bar was inclosed in the helices, from $\frac{1}{3}$ to $\frac{1}{2}$ less. The most striking results, however, from these coils, was the immense length of the terminal secondary or separation spark. When the current was allowed to attain its full power, the sudden separation of the wires produced sparks *eight inches* in length. When the separation was slow, the sparks were short and spread out more like a flame. An extraordinary change was produced in the character of this secondary spark by magnetic action. When the circuit was broken at a distance of several feet from the magnet, the spark was attended with very little noise. But as the point of separation approached the magnet, the noise increased, until, when the circuit was broken on the pole of the magnet, the report was as loud as a pistol, and the spark diminished in length, and spreading out as large as the palm of the hand. The secondary spark was found also to obey the same rotative or tangential action as the conductor itself. (Vol. 11, No. 33, page 191, March, 1851.)

Soon after the publication of these interesting results, M. Ruhmkorff, an instrument-maker in Paris, took up the induction apparatus with a view of increasing its electrostatic powers. Du Moncel, the author of a special treatise on the Ruhmkorff coil, says that "Ruhmkorff, profiting by the experiments and observations of Massón & Breguet, sought to provide for a better insulation of the wire of the secondary circuit, and to prevent the loss of static electricity;" and, to accomplish this, he "*drowned*" the wire in shellac. The fine wire coils were very long—in some cases even ten miles. He also increased the dimensions of the coil lengthwise, or in the direction of its axis, and diminished its transverse diameter, in comparison with coils that had generally been made in Europe. In fact, they were made more according to the form of Prof. Page's coils. The terminals of the secondary wire were attached to glass pillars, and the circuit was broken by the McGauley circuit-breaker, heretofore described. Becquerel (Traité de Électricite et de Magnetisme, 1856, p. 240) calls it the circuit-breaker of Dr. Neef et De La Rive, which he figures on page 213, and, also, page 239. Du Moncel calls it the circuit-breaker of De La Rive, although, on page 376, he gives the priority to

Dr. Neef. The truth is, that Dr. Neef anticipated De La Rive in this matter; but states, in his own description, that the invention was given to him by his friend, Mr. Wagner. As we shall see in the chapter on Circuit-Breakers, Prof. McGauley described it more than two years before Dr. Neef. With this apparatus, Ruhmkorff obtained sparks in air somewhat less than four-tenths of an inch long, and very beautiful luminous effects in vacuuo. Sparks could be taken from either extremity of the secondary wire alone, and the shocks were dangerous to encounter. Subsequently, Fizeau discovered that the connection of a condenser with the primary coil had the effect of suddenly arresting the secondary current of this coil, and to greatly increase the intensity of the current of the secondary wire. At his suggestion it was applied to the Ruhmkorff coil, and at once gave it a celebrity which, perhaps, otherwise it might not have attained. We shall dilate upon this subject hereafter. This coil was announced in this country, in Silliman's Journal, by Prof. J. Nicklès, in 1853, (vol. 15, page 114,) and excited but little interest at the time. The editors of the Journal added, in a foot note to this communication, that "there were many points of resemblance between the apparatus of M. Ruhmkorff and the Compound-Magnet and Electrotome of Dr. Page, whose apparatus appeared to be but little known in Europe." And, in reference to the circuit-breaker described by Nicklès, the editors said, that "this apparatus is very nearly identical with the vibrating armature break-piece of Dr. Page and Daniel Davis, for more than ten years in use in all the forms of electro-medical apparatus. The American contrivance has the additional convenience of an easy adjustment for the rapidity of its vibrations." In the latter part of 1854 and beginning of 1855, Poggendorff published the results of his experiments with Ruhmkorff's coil, and suggested several modifications, none of which, however, seem to have been of much practical importance, except that of making the secondary coil, in several sections, to avoid the tendency of the intense current, to pass through from layer to layer of the wire, and injure the coil. This division, however, of an intensity coil was not new at this time, the same device having been patented in England by Edward and Charles Bright, October 21, 1852; No. of patent, 14,331. See 14th claim. It was applied to the coils of relay magnets, but for the same purpose and upon the same principle as Poggendorff's suggestion. In 1856 the coil began to make some stir and progress among electricians. Emile Stohrer described, in Poggendorff's Annals for May, 1856, a large coil, with the secondary, made in three sections, which gave sparks five-twelfths of an inch without a condenser, and fourteen-twelfths with it, showing some advance on Poggendorff's coils.

In the Lond. and Ed. Phil. Mag., November, 1856, vol. 12, page 377, Mr. Hearder, instrument-maker, of Plymouth, England, announced a coil which gave sparks with a condenser one inch in length.

In the same vol. for December, pages 444, 445, Mr. Hearder announced a still more powerful coil, from which he obtained sparks between 2¾ and 3 inches, and 8 and 9 inches in length in the flame of alcohol.

In the same vol., page 519, Mr. Bently, who appears as a rival of Mr. Hearder, described his coil as furnishing sparks 2 inches long.

In vol. 13, same work, May, 1857, Mr. Hearder described a coil from which he obtained sparks 4 inches long. These developments indicated steady advancements upon Ruhmkorff's instruments, and the improved results were due to superior insulation. Quite a dispute was maintained for some time between Mr. Hearder and Mr. Bently on the merits of their coils—Mr. Hearder claiming his superiority over Ruhmkorff by virtue of the use of oiled silk as an insulator between the layers of the secondary. It happens that the use of *oiled silk* in this way, as an insulator, was not new. In Sturgeon's Annals, the editor describes (vol. 1, pages 76, 78, 1836) a coil made for an electro-magnet, exhibited in London in 1833, in which there were six layers of wire, each separated by oiled silk. Ruhmkorff's insulation of each layer by *shellac* for the secondary coil, was published fourteen years before by Professor Callan, (Sturgeon's Annals, vol. 1, page 297,) and insisted upon by him as indispensable to the production of intensity-effects from a secondary coil. The only decided novelty of any particular value in the construction of the coil was made in this country by Mr. Edward S. Ritchie, of Boston, Mass., in 1852. In a letter from Mr. Ritchie to Sill's Journal, dated Boston, May 2, 1857, he describes a coil with a peculiar mode of winding the wires of the secondary, by which he obtained six inches sparks. This letter was published in the September No. of Lond. Ed. Phil. Mag., December, 1857, vol. 14, page 239.

In a subsequent letter to the editors of this Magazine, Boston, October 2d, 1857, Mr. Ritchie states that he constructed a coil for Columbia College, New York, in July, 1857, which gave sparks "*ten and a half inches long.*"

In the Edinburgh New Philosophical Journal, vol. 6, page 189, July, 1857, is a communication from Professor William B. Rogers. describing one of Ritchie's coils, giving sparks 6½ inches long. He also describes the mode in which the secondary coil is made up of a succession of conical layers.

Mr. Ritchie's reputation soon became deservedly celebrated, and orders for his coils were received from Europe. Mr. Gassiot, of London, describes one in the Lond. Ed. Phil. Mag. for May, 1858, page 446. This coil gave sparks of the enormous length of 12¼ inches by accurate measurement, and Mr. Gassiot said he was confident it would give 15 inches, but was afraid to force it too much, lest the insulation should be penetrated. Mr. Gassiot speaks of the coil as made up in sections, and that "the method of winding had been before suggested by Poggendorff." In this he was in error. Poggendorff suggested "dividing the coils lengthwise into several sections," and, to use his own language, "each section being wound up in the usual manner" of superposed layers. Mr. Ritchie's coil was, indeed, made of sections, but there were as many as spires of wire in the whole length of the instrument, and each of these was wound up, not in the usual way, but as a flat spiral. A sectional arrangement, which necessitated a new mode of winding, and an entire change in the construction and power of the coil, is a very wide departure from Poggendorff's plan, or rather, Messrs. Bright's plan. Thus we find that *the commencement and preparation of the induction coil, which we shall hereafter characterize as the electrostatic coil, must be accredited as American inventions.* Of this we shall speak further in another chapter. After Mr. Ritchie's invention was known in Europe, a new impulse was given to the subject, and coils of nearly equal power were brought out by Ruhmkorff and other instrument-makers. In the chapter devoted to the coil, we shall re-publish an article from the Franklin Journal, showing the manner in which M. Ruhmkorff became acquainted with Mr. Ritchie's improvements, and his previous refusal to accept a challenge to furnish a coil equal in length of spark to Mr. Ritchie's. In the application of Fizeau's condenser, we recognize a discovery and invention of high value and interest, which will abide as a monument of his learning and genius. Latterly, we have heard of coils giving sparks "*two feet long*," from coils eighty miles in length. (Noad's Inductorium, London, 1866, page 42.)

In the Lond. and Ed. Phil. Magazine for November, 1857, page 323, Prof. Callan describes, at great length, some experiments with coils, and makes many propositions. He recommends using iron wire for the secondary circuit, alledging that the current has more intensity on account of the magnetization of the iron wire, which, he supposes, assists in the reaction. On account of its cheapness, iron wire has been used many years for ordinary induction coils, but copper wire is undoubtedly superior to iron. The secondary coils made in this country by Mr. Grant, in 1842–'3, of several miles in length, and giving sparks ½ inch long, were made of iron wire. Prof. Callan also recommends, instead of the bundle of wires, to make the core of the coil of a compact helix of iron wire. We cannot accept his reasoning on this point, and are satisfied that the bundle of wires is superior.

Having completed the history of induction apparatus, we leave it to the impartial reader to decide whether we have not made good the assertions advanced in behalf of Prof. Page's claim, and justified the following conclusions:

First. The first galvanic induction apparatus, with an intensity secondary coil, was made by Prof. Chas. G. Page.—(*Silliman's Journal, vol.* 31, *No.* 1, *page* 137, *May* 12, 1836.)

Second. The first induction apparatus, by which shocks were obtained from a secondary *circuit*, was made by Prof. Page.

Third. The first induction coil, in which the battery current was caused to pass through only a portion of the circuit, while the shocks and other indications of intensity were taken from the whole circuit, was made by Prof. Page.

Fourth. The first induction apparatus, by which shocks and other indications of electricity of high tension were obtained from a purely secondary circuit exterior to the primary circuit, was made by Prof. Page.

Fifth. The first induction apparatus, in which the secondary circuit exceeded the primary circuit in length, was made by Prof. Page. (Many times the length was used.)

Sixth. The first induction apparatus, in which the secondary circuit was exterior to the primary circuit, was made by Prof. Page.

Seventh. The first induction apparatus with a secondary circuit adapted to medical purposes was made by Prof. Page.

Eighth. The first application of a self-acting circuit-breaker to an induction coil of any kind, with or without a secondary circuit, was made by Prof. Page.

Ninth. The first application of a mechanical circuit-breaker to an induction coil, consisting of a primary and secondary circuit, was made by Prof. Page.

Tenth. The discovery of the electrostatic properties of the secondary current was first made by Prof. Page.

Eleventh. The valuable and interesting discovery that the intensity of the secondary current is greatly increased by breaking the primary circuit, under a poor conducting liquid, was first made by Prof. Page. This was re-discovered eighteen years afterwards, in Europe, by Poggendorff and Foucault.

Twelfth. The first organized apparatus for the exhibition of the electrostatic properties of the secondary current was made by Prof. Page.

If more has been claimed for Prof. Page than can be sustained, the analysis of his whole title into these twelve distinct elements or specifications of claim will afford a better opportunity for criticism or contradiction than if they had been massed. The examination has been carefully made with an effort at impartiality, and a desire to place every author in his true position, in regard to the induction of currents and apparatus for their illustration.

CHAS. G. PAGE.

WASHINGTON, D. C.,
November 19, 1867.

CONTACT OR CIRCUIT-BREAKERS.

PART SECOND.

This interesting class of inventions has received a large share of attention with most writers upon Electricity and Magnetism. Du Moncel, after describing one of the earliest and rudest forms, proceeds to say: "*Plusieurs perfectionnements, entre autres la substitution des interrupteurs* mecaniques a la roue dentée, furent ensuite successivement apportés aux appariel d'induction, de sorte que ceux-ci constituerent bientot une des applications les plus importantes de la science electrique.*" Ferguson, in his recent work on Electricity, remarks as follows: "*Whatever favors the suddenness of the changes of the primary current heightens the tension of the currents induced by these changes.*" "The *break*, from this circumstance, forms an important element in the construction of all induction apparatus." These instruments were also called in Europe *interrupters* and *rheotomes.* The name *electrotome* was given to them by Professor Page. No author has undertaken as yet to classify or furnish a historical account of circuit-breakers, and this we propose to do in the following chapter.

They may be grouped in four classes.

1st. The *mechanical,* or those worked by hand.

2d. The *automatic,* or those worked by electricity and magnetism.

3d. The clock-work; and

4th. The spark-arresting circuit-breakers.

Under the mechanical class we have two divisions—the *rotary* and *vibrating.*

***The author applies the term mechanical to those circuit-breakers which we call automatic.**

First. The *rotary mechanical,* includes the revolving interrupted discs or cylinders, cog wheels, ratchet wheels, spur wheels, and sprocket wheels, with a conducting wire or spring pressing upon the interrupted surfaces of the two former, and the projecting teeth of the four last named. Also the spur and sprocket wheels revolving in mercury.

Second. The *vibrating mechanical* includes the lifters, in which wires are raised from mercury or solid surfaces by cams, and also the rasp over which the wire is drawn by hand.

Under the automatic class we have also two divisions—the rotary and vibrating.

First. The *rotary automatic,* including revolving magnets and revolving armatures.

Second. *Vibrating automatic,* including vibrating magnets and armatures, and vibrating end-pieces or hammers. These may be used to work the lifters also.

Under the *clock-work* class we also have two divisions—the rotary and vibrating.

The clock-work may be used to keep in motion any of the mechanical circuit-breakers.

The *spark arresting* circuit-breakers are those in which the circuit is broken over mercury covered with a non-conducting liquid. They are either rotary or vibrating.

There are also two important divisions of the automatic or magnetic-breakers.

The first is the kind in which the magnetic force required to break the circuit is derived from the magnetic core of the coil itself. These we shall designate *attached* circuit-breakers.

The second embraces quite a variety of little instruments of rotary and vibrating movements, and which derive their motion independently of the magnet of the coil. These we shall designate *independent* circuit-breakers.

The first kind requires no extra length of circuit, and is supposed to be more economical of battery power than the second, which requires an addition to the circuit of the primary coil equal in length to the little coil used to work the circuit-breaker. This coil is usually very short, but is in most cases made of smaller wire than the primary of the induction coil, and introduces some resistance. The extraordinary ground, however, has been taken by Professor Callan, "that little or no battery power is lost by using an electro-magnet for making and breaking contact, instead of the magnetized core of the induction coil. (See his experiments on this point, Lond. Ed. Phil. Mag., 1857, vol. 14, page 328.)

We shall briefly describe all the circuit-breakers in historical order, referring each to its proper class.

The first circuit-breaker of record was that of M. Masson, in France. In June, 1835, he presented a Memoir to the French Academy describing some experiments with a large coil of copper wire, and a battery consisting of 24 pairs, Wollaston's. The circuit, with the coil, was broken by a toothed-wheel, and shocks obtained of sufficient power to kill a cat. This, a mechanical rotary-breaker, was revolved by a band and multiplying wheel. This was not published until 1837, in the Comptes Rendus, and in the latter part of 1837 in the Annales de Chemie, vol. 66, p. 5 to p. 36, by M. Masson himself. Becquerel and Savary made a complimentary report upon this memoir at the *Séance* of the Academy, 27th March, 1836. A fuller account of the apparatus has been given in the chapter on Induction. A considerable number and variety of circuit-breakers were introduced and published in the interim by other persons before we had any account of M. Masson's breaker. The first of these was a mechanical rotary, published in the latter part of 1835 by Dr. Neef, of Frankfort on the Main, in Poggendorff's Annals (vol. 36, page 352.) It consisted of a copper wheel six inches in diameter, mounted on a vertical shaft, and provided on its upper surface with radial grooves, inlaid with wood. On this suface rested a wire or conductor, so as to press sufficiently to preserve contact, and the wheel and wire being included in the galvanic circuit, it was interrupted whenever the wire was in contact with the wood, and completed when it was in contact with the copper surface. It was used with the Voltaic pile, so as to get the benefit of contact and separation, which was well known to produce shocks when continued contact would fail to produce them. It was also used with a primary coil surrounding a bar of iron for the same purpose; and Dr. Neef proposed the use of the apparatus for medical purposes. The wheel was, as stated, the invention of Mr. Wagner, a friend of Dr. Neef.

The next record is of three, in fact four, distinct kinds of circuit-breakers, by Prof. Page, in May and June, 1836, published in Silliman's Journal, vol. 31. pp. 140, 141. These are two mechanical and one automatic, and a spark-arresting circuit-breaker. The first mechanical (R, Fig. 1) was a rasp, connected with one terminal of the coil, over which was drawn a wire connected with the other terminal. This, though simple, has proved to be very efficient, and was used by Prof. Henry in his extensive experiments on induction, (Silliman's Journal, July, 1840,) and was applied as a fixture to the base-board of most of the induction instruments made in Boston and elsewhere for many years, and is still in common use, (Fig. 4.) (Davis' Manual of Magnetism, pp. 247, 287, 296, 301.) The other mechanical kind was a spur or star-wheel, with its teeth made to dip into mercury. The automatic kind was a spur-wheel, with its teeth dipping into mercury, and propelled by the action of a magnet. It was, in fact, the instrument known as Barlow's spur-wheel. This was the first known automatic circuit-breaker, and particular *importance* was attached to this self-acting property, especially for medical purposes, as it enabled the operator to "*dispense with the use of an assistant*" for breaking the circuit; and, furthermore, produced a rapid and regular succession of shocks, the frequency of which could be regulated at pleasure, by simply moving the magnet towards and from the wheel. The mercury in these experiments was covered with water or naptha when high intensity effects were to be produced. The water or naptha not only diminished the sparks, but prevented the escape of noxious fumes, and kept the surface of the mercury in good condition. This we call, by way of distinction, on account of its practical importance, the spark-arresting circuit-breaker. When the spark is to be exhibited the mercury must be uncovered.

The next contact breaker was by Mr. Sturgeon, published in the October No. of the Annals, (vol. 1, page 41,) under date of "July 4, 1836." It consisted of "one of Mr. Barlow's stellated wheels soldered to an iron spindle, and put into a rotatory motion by a wheel and band." This was used to make and break the circuit of an intensity battery to obtain a succession of shocks and charges of Leyden jars, or an extensive condenser made of "varnished Bristol board." No coil was used. Mr. Sturgeon stated that the shocks from the condenser, used in connection with a water battery, were equal to shocks produced by an acid battery. This circuit-breaker was similar to the mechanical circuit-breaker of Prof. Page, and that of M. Masson, above described; and it will be curious to note, as we proceed, how many experimenters adopted this same contrivance as original with themselves.

The next described circuit-breaker is by Mr. Sturgeon, of England, dated September 24, 1836, published in October, 1836. (Sturgeon's Annals, vol. 1, page 69.) It was of the mechanical class, rather rude, and extemporized for certain experiments with two independent coils. One of the conducting wires rested by its end or point upon a terminal disc of copper, bright and roughened on its upper surface, and the wire was made to vibrate to and from the plate, by the "application of a rough-edged wheel" turning against the wire.

The next of record is by Charles Barker, of England, dated Gosport, December 12, 1836; published January, 1837. (Sturgeon's Annals, vol. No. 2, page 158.) No description is given, but a perfectly plain engraving is given showing its construction and operation, in connection with a coil, on an electro-magnet. Two points or blades on the end of a revolving shaft are made to revolve in a mercury trough, and thus break the circuit—the permanent connection of the shaft with one pole of the battery being preserved by an entire copper disc, upon the shaft revolving in a separate mercury cell or trough. The shaft was driven by a multiplying wheel, band, and pulley. It is essentially the same as the wheel of Prof. Page.

The next record is by Prof. Page, dated "Salem, April 19, 1837," describing four varieties of automatic circuit-breakers. (*Silliman's Journal, vol.* 32, *pp.* 355, 356, 357, 358.) The first is a Ritchie magnet fitted so as to have its terminals revolve in a glass cell, and have the mercury covered with water.

It is quite a remarkable fact, that this little instrument, invented by Dr. Ritchie, and described by him in Philosophical Transactions, 1833, page 320, should have been subsequently adopted by six or more electricians in Europe, at various times, each suggesting it as original with himself. Among the names are Sturgeon, Lockey, Becquerel, Bianchi, and Du Moncel. It was in some respects well adapted to the purpose, but no one of them seems to have been aware of the importance of covering the surface of the mercury with water or other other liquid, without which this particular variety is comparatively of little practical value, for the revolution of the wires often drags the mercury across the partitions between the mercury cells, and thus arrests the motion, "which is, to a great extent, prevented by the use of water" or other liquid. The spark-arresting function of the liquid is, however, of the most consequence.

The second variety is a miniature vibrating electro-magnet, with the wires and connections so arranged that its polarity is reversed at every vibration, which is kept up in a rapid manner by the alternate attractions and repulsions of a permanent magnet. The motions of the vibrating magnet are restrained and regulated by a set screw, and the connecting wires of the circuit are dipped into and lifted out from the mercury cups.

The third variety is a repetition of the second, the mode of suspension being changed, and more simple than the last.

The fourth variety is a revolving electro-magnet, carrying upon its axis interrupted discs revolving in mercury cells, also star wheels upon its shaft, to break the contact with mercury or other metallic conductor.

The spark-arresting principle is applicable to all these varieties.

The next in order is the *repeater* of Prof. Callan, of Maynooth College, Ireland, published in 1837. (April No. of Sturgeon's Annals, vol. 1, p. 229.) This was a *mechanical* circuit-breaker, and consisted of a forked wire, made to vibrate in and out of mercury cups alternately. The motion was derived from an escapement wheel turned by hand, the wire being attached to the escapement shaft. It was used with a primary and secondary coil upon an electro-magnet. In an article communicated by Prof. Callan to the Lond. Edin. Phil. Magazine, (vol. 9, page 477,) for December, 1836, he says that he has devised an instrument for breaking the circuit rapidly, which might have been this repeater, but, as he gives no description whatever of its construction, we must adopt the date of publication in Sturgeon's Annals.

In vol. 33, No. 1, Sill's Journal, page 191, Prof. Page describes, under date of August 23, 1837, two new rotating instruments, susceptible of use as circuit-breakers. They were not intended for that use, and, in fact, are inferior as automatic-breakers to many others. But allusion is made to them here, as Dr. Golding Bird introduces them in his Natural Philosophy edition of 1839 as circuit-breakers. One is a flat coil, rotating by change of polarity between the poles of an electro-magnet, and the other a helix of copper wire, revolving by the same means.

In the same vol. (33) Sill's Journal, No. 2, pages 376, 377, Prof. Page describes a new form of electrepeter or commutator. It is substantially the same as that adopted in 1851 by Ruhmkorff for his induction coils. A description also is given of a mechanical electrotome, rather more fanciful than useful, and need not be described. They were completed in September, 1837.

The next circuit-breaker on record is that of Prof. McGauley, of Dublin, exhibited by him some time in September 1837, at the meeting at Liverpool of the British Association. No description of this appeared until the publication of proceedings in 1838. In the January No. of Sturgeon's Annals for 1838, page 73, an indistinct allusion only is made to this invention. By way of distinction, we shall call this the *hammer* circuit-breaker. A soft iron ball is attached to one end of a vibrating bar, and a forked wire dipping into two mercury cups attached to the other end. The ball being attracted by the pole of the magnet is drawn downwards, and raising the opposite end of the bar, lifts the forked wire from the mercury cups, and breaks the circuit, which was complete through the wire when it dipped into the mercury. This was the first automatic circuit-breaker of European invention, and was of some importance, inasmuch as it was in one respect the type of many of the most important circuit-breakers now in use. It was, however, devoid of any means of adjustment, no provision being made by which the *retractile* force of the ball could be varied.

This essential element of every circuit-breaker, as we shall soon see, was accomplished by Prof. Page, who soon after, invented the same device of the ball and vibrating bar, before any description of McGauley's invention reached this country.

The next was a mechanical circuit-breaker, a lifter, by Mr. Sturgeon, described before the Lond. Elec. Society, August 5th, 1837, and published in the October No. of the Annals, vol. 1, page 479, with an engraving. A wire dipping into a mercury cup is lifted out by means of a revolving cam on a pulley shaft, driven by a band from the multiplying wheel. Mr. Sturgeon also describes a notched zinc disc, over which a spring wire was made to revolve rapidly and exhibit a circle of sparks.

The next is also a mechanical circuit-breaker by Mr. Bachhoffner. It is simply the ratchet-wheel and spring pressing upon its teeth. The wheel is turned by a crank. (Sturgeon's Annals, vol. 1, p. 496.)

The next in order is a mechanical circuit-breaker by Mr. Clarke. (Sturgeon's Annals, vol. 1, p. 499.) It is a star-wheel of copper, revolving in a glass vessel containing mercury. Mr. Clarke also describes the use of a rasp for breaking the circuit, which he states answers very well for certain purposes, but prefers the wheel for medicinal purposes. The editor, Mr. Sturgeon, in a lengthy note, administers the following rebuke to Mr. Clarke, which we copy in full, because of its general applicability:

"It must at all times be gratifying to philosophers to observe that their discoveries and inventions are of sufficient importance to demand the attention of others, and to inspire in instrument-makers a spirit of emulation to excel in their attempts to improve even the most trifling arrangement. On the other hand, it must be allowed that there is a respect and gratitude due to philosophers, which those who profit by their discoveries are but too seldom disposed to acknowledge. Notwithstanding the trivial alterations he may think proper to make, the fame of the instrument-maker could not possibly suffer by a candid acknowledgment of the source of his information on any point whatever relative to the original invention; and the least degree of courtesy that could be expected from him, would be to permit the discoverer or inventor to have a priority of publication. Mr. Clarke will observe, however, that we have not hesitated to give publicity to his paper, but it is our duty to state that Mr. Clarke's method of opening and closing the battery-circuit is similar to that employed by Mr. Barker, (see Fig. 42, plate 6;) and that the original employment of the spur-wheel and mercury for this purpose was by Mr. Page. See the postscript to that gentleman's paper, page 293 of this volume.—*Edit.*" Mr. Sturgeon might also have referred to that same paper for the original use of the *rasp* for this purpose by Mr. Page.

In the transactions of the London Electrical Society for 1837, page 133, Rev. Mr. Lockey describes an automatic circuit-breaker made by a Ritchie magnet. His modification consisted in covering the mercury cells with perforated discs, allowing the mercury to rise through and above the perforations, so as to get more than the two breaks in the circuit, due to the ordinary construction. It amounted merely to inserting several partitions in the mercury cells instead of two. It is probable that the actual number of breaks in a given time was not much increased, as the speed of the magnet was necessarily diminished.

The next circuit-breaker described is one by Dr. Golding Bird, of London. It was automatic, and a repetition of Prof. Page's vibrating magnetic bar, described in the October No. 1837, of Sill's Journal, and mentioned above. It seems to have been a great favorite with Dr. Bird, and he gave it a conspicuous place and preferment in his work on Natural Philosophy several years afterward. It was first described by him in the Lond. Ed. Phil. Journal for January, 1838, (vol. 12, page 18,) with an engraving. It is deficient in the essential feature of adjustment found in Prof. Page's instrument. After expatiating upon the importance of the invention, especially in the medical application of the current of induction, by reason of its automatic character, dispensing with the use of an assistant to break the circuit, as was necessary with the mechanical breakers, he states that when he "made the invention it was original with him," but that the "credit of priority must be given to Dr. Page." His article is dated November 2d, 1837.

The next in order is a mechanical circuit-breaker by Mr. J. C. Nesbitt, described in Sturgeon's Annals, vol. 2, No. 9, March, 1838, page 203. Mr. Nesbitt's letter is dated Feb. 10, 1838. It consisted of a small brass wheel, with numerous holes in its periphery filled up with wood. The wheel being always in the circuit, a wire spring, connected with one terminal of the coil resting upon the circumference of the wheel, broke the circuit as the wooden plugs passed under the wheel. It was a modification only in form of the lightning wheel of Dr. Neef.

The next in order was an automatic rotary-breaker by Prof. Page. This was described in Sill's Journal, vol. 35, page 262. The communication dated November 13th, 1838, states, this was invented in February, 1838. An armature or light bar of soft iron is made to revolve rapidly between the poles of an electro-magnet, the current being intercepted at each half revolution of the armature by a break-piece on its shaft. This instrument (see Fig. 4) is figured in connection with one of Page's coil in Davis' Manual of Magnetism, edition of 1842, page 186. The rasp circuit-breaker is also on the same base-board.

The next circuit-breaker is also by Prof. Page, and described on page 258, in the same communication with the last named, as completed in April, 1838. It was also fully described in Davis' first Manual, Nov. 13, 1838, pp. 45, 46, 47, 48, 49. This was an automatic vibrating circuit-breaker, and consisted of a cylindrical piece, or hammer of soft iron (G, Fig. 2) attached to one end of a stout vibrating wire, (E,) somewhat after the manner of McGauley's circuit-breaker. The wire was furnished with two points—one M, at the extremity, and the other H, near the axis of vibration, and these points or branches dipped into mercury cups M, N, placed upon the top of the coil. The circuit was completed through the mercury cups by the branches. The important difference, however, between this and Prof. McGauley's, was the provision for adjustment in the Page circuit-breaker. McGauleys had none, while Page's adjusted both the distance between the magnet and the soft iron hammer, as we shall call it, and the retractile force of the hammer. This latter feature is indispensable to a good circuit-breaker, and exists in most that are in use at the present day. Instead of a vibrating brass beam used by Prof. McGauley, Page used a stout copper wire, (C;) and as one of the branch wires (H) rested upon the bottom of the cup, (N,) the mere bending of this wire up or down adjusted the distance between the hammer and the end of the magnet. The retractile force of the hammer was adjusted by the regulating ball (L) on the screw-stem, (O,) connected with the axis of vibration, and projecting over on the side of the long arm of the vibrating wire. The screwing of this ball back and forth on the stem regulated the retractile force of the hammer by counter-balancing more or less of its weight. Another improvement was in the form of the hammer, the ball of McGauley being an unfavorable form for magnetic induction and attraction. The most important feature, however, of Prof. Page's instrument was the provision for spark-arresting. The mercury cup (M) in which the circuit was broken at the end of the wire was large, and made of glass, and designed for the use of water, oil, naptha, alcohol, or other liquid over the surface of the mercury, for the purpose of increasing the intensity of the secondary current. Another feature of some value, was placing the mercury cups in the line of the vibrating wire, by which the cup (N) in which the circuit was not broken, might be near the axis of motion. There was not really much necessity for this mercury cup, as the constant connection could have been maintained through the pillars supporting the axis (K) of the wire. It had a use here, however, being designed for a check to the downward motion of the wire.

In the same communication is also described another automatic vibrating circuit-breaker by Prof. Page, and one of chief importance, as it is the circuit-breaker (with only a slight difference in arrangement) which has been in use ever since its invention, in connection with coils used for medical purposes. In the induction coils for medical use, and in others used for scientific illustration, it has always been customary to regulate the intensity of the secondary current by the partial removal of the bundle of wires forming the magnetic core. This, of course, precluded the use of the *hammer* circuit-breaker or any of the class where the magnetic core was the source of motion, and required an independent current-breaker, and to this end the vibrating armature was specially adapted, and much superior to any of the rotary devices, for the armature could be regulated with ease and precision as to its distance from the little magnet and its retractile force. Sill's Journal, vol. 35, No. 2, page 267. Davis' Descriptive Catalogue, November 1838, pages 32, 33, 34.

On page 51 of this Manual Catalogue, Prof. Page's coil for medical use is described with the revolving armature attached as the circuit-breaker. (Figs. 4 and 7.)

On page 52 of the same work, is another circuit-breaker of the hammer kind, in which the mercurial connections were dispensed with, and the retractile force of the hammer controlled by a spring. The circuit was completed by contact with two wires at its sides, and the attraction of the hammer then caused the separation of the hammer from one or both of the wires, and broke the circuit. It was inconvenient, and only of importance as showing the use of solid connections, and the action of a spring in forcing the hammer back from the magnet.

In vol. 34, page 165, of Sill's Journal, July, 1838, Prof. Page describes a spark-arresting circuit-breaker of the mechanical order. It was used in addition to the ordinary break-piece of the magneto-electric machine to break the circuit at any desired point in the rotation of the armatures. A balance beam, having a branching copper wire at one end to dip into two mercury cups, (one of which was of glass,) was caused to vibrate by an adjustable cam on the shaft of the machine. The effects produced by this circuit-breaker have been already described.

In the same vol., page 371, Prof. Page also describes a cylindrical circuit-breaker on the shaft of the magneto-electric multiplier, which was worked either mechanically by the multiplying wheel and band, or automatically, *ad libitum*, according to its adjustment in relation to the position of the armature. It consisted of a copper ferrule on the shaft, the middle part of which was entire, as a bearing for the wire for constant connection, and on either of this, dissected portions filled with ivory for a bearing for the cut-off wires.

In the third vol. of Sturgeon's Annals, July 1838, page 33, the editor describes three circuit-breakers. The first is a Ritchie magnet, with only this peculiarity: that, in order to increase the number of breaks, he introduces two extra partitions in the mercury cells, and thus gets four sparks in a revolution instead of two. The other two present no novelty, being merely divided or interrupted metallic surfaces, with different metals introduced to vary the color of the spark.

In January 1839, Dr. Neef, of Frankfort, published in Poggendorff's Annals a description of a hammer circuit-breaker, which was mostly a repetition of Prof. McGauley's circuit-breaker, the only difference being in the arrangement or position of the point where the circuit was broken, it being in this case directly in contact with the hammer itself. Like McGauley's instrument, it contained no means of adjusting the retractile force of the hammer, and in this respect was inferior to the hammer circuit-breaker of Prof. Page. It is stated that this was exhibited to a meeting of philosophers at Freidburg, in September, 1838. By a singular error, this was called Dr. Neef's circuit-breaker by De La Rive, Du Moncel, Becquerel, and, in fact, every author we have met with; but Dr. Neef distinctly states that the invention was "given to him by his friend, Mr. Wagner." It was the kind of circuit-breaker adopted many years after by Ruhmkorff in his coils.

In the January No. of Silliman's Journal, 1839, vol. 35, page 112, is a description by Prof. Page of a rotary automatic circuit-breaker and electrepeter, or commutator as it is more commonly called, the direction of the current being reversed at each break of the circuit. A permanent magnetic bar, attached to an upright shaft, is suspended so as to revolve freely under the influence of a flat spiral, or the pole of a magnet. The shaft carries two wires insulated from each other, the upper terminations of which are bent downwards, and revolve in mercury cells concentric with the shaft. These cells are connected respectively with the poles of the battery. The lower ends of the wires turn in semicircular mercury cells, divided by two wooden partitions, precisely as for the rotation of the Richie magnet. These semi-circular cells are respectively connected with the ends of the coil or spiral. The end of the bar-magnet being brought near to a magnetic pole, or the bar being laid upon a flat spiral, will be made to revolve, changing the direction of the current through the coil once in every half revolution. This is the only automatic commutator for induction coils we have met with. They have generally been worked by hand.

The next in order is the clock-work electrotome, by Dan'l Davis, described in his supplemental Catalogue published in the latter part of 1839. By a very simple adaptation of clock-work, the ends of a copper wire are caused to dip alternately into mercury cups, and thus break the circuit in a very rapid manner. The wire is fastened to the arch or to the shaft of an escapement, and the scape-wheel is actuated by a coiled spring concealed within one of the pillars of the apparatus. There have been several clock-work electrotomes, described by De La Rive, Du Moncel, and others, but no date of invention or introduction is given, and they differ in no important particular from that of Davis, and were all probably several years subsequent to his. They are mostly out of use, being expensive, liable to derangement, and difficult to adjust as to the rate of vibration. For many years subsequent to this period very little attention seems to have been given to the subject of circuit-breakers. There was produced, however, one interesting and important modification of Prof. Page's vibrating armature-electrotome, the authorship of which we have been unable to ascertain with accuracy. It consisted in attaching the armature to a spring, and causing it to approach and recede from the little magnet in a direction parallel to itself, instead of vibrating in the arc of a circle. Both of these vibratory or reciprocating movements of the armature were described by Prof. Page, in the same communication to Silliman's Journal, under date of November 13, 1838, Vol. 35, No. 2—the direct movement on page 264, and the vibration in the arc of a circle, page 267. But, notwithstanding the merit of an independent circuit-breaker, (that is, one not actuated by the magnetic core of the coil,) in which a vibrating armature was employed, belongs to Prof. Page, still, in the modification of which we now speak, there is a convenience and simplicity which has secured for it general introduction wherever an independent circuit-breaker is employed. This is more especially the case in the induction coils for medical purposes. The armature is attached to one end of a flat spring of brass, the other end being fastened to a little post. Over this spring projects downwards from another post, a screw, bearing on its lower end a tip of platinum, and this tip comes into contact with a piece of platinum secured to the upper side of the brass spring; the screw and the spring being so adjusted that they are in contact when the armature is a short distance from the poles of the little magnet, which stands upright upon the base board of the instrument. It is shown in its most approved form in Figs. 5 and 6, in which the spring holding the armature passes through a ring on the top of the pillar bearing the adjusting screw, thus bringing the two pillars into line. This elegant arrangement was made by Dan'l Davis, of Boston, and we are inclined to think that the first modification originated at his establishment in the early part of 1843. In the 1848 edition of Dr. Golding Bird's Natural Philosophy, we find a discription and engraving of this circuit-breaker, in an awkward form, a disc of iron being used instead of an armature, and this was attracted towards two upright bars of iron fixed in a board. Whether it is contained in the edition of 1843 or 1844 we do not know, as we have not been able to find that edition. It is not in the edition of 1839. From the very rude character of the figure in the edition of 1848, we infer that it was there published for the first time in his work. Instead of an armature, McGauley's disc of iron was used. Dr. Bird does not give the origin of the instrument, although he says it was "far superior to the one he contrived." This *one* we have already noticed, as the instrument which Dr. Bird finally accorded to Dr. Page. We find the improved circuit-breaker in the Catalogue of Jos. M. Wightman, of Boston, in 1846, and the still further improved form in Davis' Manual of Magnetism, edition of 1847. We do not find it in the 1842 edition of Davis' Manual. In the London Electrical Magazine for April, 1844, page 280, Rev. Mr. Lockey, in describing the action of buried plates with a coil, says "a constant bee like hum* was kept up by the rapidity with which contact was made and broken in that coil apparatus, (I forget its author's name,) in which contact was broken by the attraction of a disc of iron toward a bundle of iron wire." To this the editor of the Magazine adds a note, stating that "he believed it originated with Dr. Golding Bird." The invention is attributed by Dr. Bird to Prof. McGauley, with the exception of the bundle of wires, which was not known when Prof Gauley made his invention. The allusion of Mr. Lockey is to the attached species of circuit-breaker where the piece of iron (hammer) is attracted by the bundle of wires—that is, the magnetic core of the helix, as in Prof. Page's coil, and not to an independent circuit-breaker. Dr. Bird originated but one circuit-breaker, an independent, to which we have already several times alluded.

In Peschel's Elements of Physics, published in German, in 1842, a description is given of "Mr. Wagner's circuit-breaker," which is identical with that described by Dr. Neef 1839. No date is fixed, but this account is confirmatory of the statement we have made, that Dr. Neef was not the author of the automatic circuit-breaker which erroneously bears his name.

We find nothing further recorded of interest on circuit-breakers from this time until that of the distinguished Foucault, in France, in 1856, an account of which was published in the Compte Rendu for July, 1856, vol. 43, page 44. This automatic independent circuit-breaker was so much like that of Professor Page's spark-arresting circuit-breaker, Fig. 2, that a particular description is hardly necessary. It consisted of a wire or slender-balanced beam, bearing two branches of wire at one end, dipping into the mercury cups, and at the other end a small armature to be attached by the poles of a small electro-magnet. The retractile force of the armature was regulated by a sliding weight, as in the circuit-breaker of Professor Page. It was particularly designed for use with the Ruhmkorff coil; and at this time, all the coils imported from Paris to this country, are accompanied with a Foucault circuit-breaker. Its object is precisely the same as that of Professor Page's circuit-breaker of 1838, viz., that of breaking the circuit with mercury covered with alcohol or water, for the purpose of arresting suddenly the passage of the extra current in the primary coil, and thus removing the obstacle to the complete reaction of the magnetic forces upon the secondary wire. The coincidence of these inventions, *eighteen years* apart, is quite remarkable.

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* All the vibrating automatic circuit-breakers, when used with solid connections, produced a humming or musical tone when adjusted for rapid movement, and Mr. Lockey proposed to call them galvanic wasps. Becquerel says that in France they had gained the name of tremblers. (*Trembleur.*)

The last circuit-breaker we shall notice is one described in Noads' Inductorium, 1856, page 39. The account leaves it to be inferred that it was the invention of Mr. Ladd, for whose particular benefit the Inductorium was written. Instead of a light hammer piece falling by its own weight after the attraction of the magnetic core has ceased, with no mode of regulating its retractile force, as in the McGauley circuit-breaker, (called "Neef's hammer" by Mr. Noad,) the hammer is on the end of a stiff spring, the tension of which is regulated by a set screw, and thus the attraction may be sufficiently slow to allow the magnetism of the core to rise to its maximum. Mr. Hearder introduced this device with his coils in 1857, (Lond. Edin. Phil. Mag., Sept., 1837, page 238,) and claimed it as an improvement on the coils of Ruhmkorff, who used merely the gravitating hammer of invariable weight or retractile force. The circuit-breaker of M. Foucault had also this adjustment, but this essential feature of a circuit-breaker was first introduced by Professor Page in his circuit-breaker of 1838.

The little independent circuit-breaker, Figs. 5 and 6, made by the reciprocating armature, and so much in use for medical machines, is defective in this respect. The tension of the spring may be varied somewhat by the set screw, which adjusts the pressure or force of contact; but, in so doing, it brings the armature nearer to the magnet, thereby increasing the attractive power in a rapid ratio. It is desirable to be able to adjust the distance of the armature, as well as its retractile force, and a perfect circuit-breaker, whether with mercurial or solid connections, should combine both capabilities. By referring to the Page circuit-breaker of 1838, it will be seen (we have already explained how) the distance of the hammer from the magnet was regulated at pleasure, while the retractile force of the hammer could be varied without changing the distance of the hammer from the magnet, by means of the sliding weight.

The great importance of this function of resistance or retractible force is well illustrated by Mr. Noad in his Inductorium, pp. 40, 41. He remarks: "The influence exerted by the resistance thus set up to the rupture of the battery contact, on the strength of the induced current, is far greater than could have been anticipated. The instrument we have been describing gives, between the terminals of the secondary, when the adjusting screw is entirely relaxed, thin, thready sparks about 1½ inch long; but when the spring is strained to its utmost, brilliant flashes, upwards of 4 inches long, pass continuously. The control which this form of breaker gives to the operator, while performing experiments in which considerable variations in the power of the induced current are required, renders it of great value."

In regard to the electrotome or circuit-breaker used by Ruhmkorff, we must insist upon the cognomen of the McGauley circuit-breaker or hammer, instead of the "Neef hammer." We prefer to give things their right names and credit where it is due. Where a distinct principle of construction or operation has been discovered or invented, trifling changes of arrangement of the parts should not be regarded as changes of merit to the oblivion of original authorship. For instance, such a change as that of dispensing with mercurial connections and substituting solid connections. It has always been known that the two were interchangeable at pleasure; and, since the first days of the electro-magnetic engine, the magneto-electric machine, and the mechanical circuit-breakers, the substitution has been common. We will refer only to a single instance. Mr. Sturgeon, in describing his vibrating contact-breaker, August 5, 1837, (Sturgeon's Annals, vol. 1, page 479, and plate 15,) exhibits both kinds of connection, to be used at pleasure. Becquerel, however, seems to settle this point for us. While describing the Ruhmkorff coil, (*Traité d'Electricité et de Magnetisme, vol.* 3, *page* 240,) says: "This interrupter is disposed absolutely as that of De La Rive, figured on page 213." On turning to page 213, we find a vibrating wire, furnished with a hammer near its middle portion, while its free end dips into a mercury cup. Inasmuch, therefore, as Dr. Neef did not invent *any* hammer circuit-breaker, and Prof. McGauley did originate the hammer circuit-breaker more than a year before Dr. Neef described a similar invention by Mr. Wagner, we think it just to say that Ruhmkorff employed the McGauley circuit-breaker or hammer in his coils, and equally just to decide that Mr. Ladd, Mr. Hearder, and M. Foucault employed the Page circuit-breaker.

We would not detract in the least from those who take pride in special arrangements, while we charaterize the distinctive features of those which must be regarded as types of whole classes. Generic distinctions must be preserved, however much the species and varieties multiply.

In summing up the subject of circuit breakers, we are led to the following conclusions, viz:

First. The first mechanical circuit-breaker used with an induction coil was by M. Masson, of France.

Second. The first automatic or self-acting circuit-breaker used with an induction coil was by Prof. Page.

Third. The first circuit-breaker, whether mechanical or automatic, used with an induction coil having a primary and secondary circuit, was by Prof. Page.

Fourth. The first *independent* automatic circuit-breaker used with an induction coil was by Prof. Page.

Fifth. The first *attached* automatic circuit-breaker used with an induction coil was by Prof. McGauley, of Ireland.

Sixth. The first *adjustable* automatic circuit-breaker, whether *independent* or *attached,* used with an induction coil, was by Prof. Page.

Seventh. The first mercurial circuit-breaker used with an induction coil was by Prof. Page.

It is not intended by this to cover the act of breaking the circuit by lifting by hand a conductor from a mercury cup; but distinct organizations, whether mechanical or automatic, for breaking the circuit rapidly, in which mercury was used.

Eighth. The first automatic *attached* circuit-breaker, in which the retractile force of the hammer was adjustable, so as to be increased or diminished at pleasure, was by Prof. Page.

Ninth. The first spark-arresting circuit-breaker used with an induction coil was by Prof. Page.

Tenth. The first *attached* circuit-breaker which combined the means of adjusting the retractile force of the hammer and its distance from the magnet was by Prof. Page.

Eleventh. The first use of an automatic circuit-breaker with an induction coil for remedial purposes was by Prof. Page.

Twelfth. No novelty or improvement in principles of construction or operation has yet been made in circuit-breakers that is not embraced in the fifteen different kinds of circuit-breakers invented by Prof. Page prior to 1840.

CHAS. G. PAGE.

ON THE ELECTROSTATIC PROPERTIES OF THE INDUCTION COIL AND MAGNETIC-ELECTRIC MACHINES.

PART III.

The opinion was entertained by men of science, at a very early period in the history of Galvanism, that it could be identified with static electricity. After the erection of extensive compound batteries, it was soon found that electrical tension was manifested at their poles, attractions and repulsions were produced, and Leyden jars or batteries charged. The dry piles were capable of exhibiting these phenomena for several years. The most important test, however, and one which science justly demanded was the projection of the spark between separated poles. Sir Humphrey Davy stated that 2,000 pairs Wollaston plates gave a spark $\frac{1}{30}$ to $\frac{1}{40}$ inch in air and $\frac{1}{2}$ an inch in *vacuuo*. Mr. Children stated that 1,250 pairs gave sparks through $\frac{1}{50}$ inch. Dr. Henry, in his Elements of Chemistry, and Dr. Turner, in his Chemistry, edition of 1840, both state that the current from a galvanic battery was capable of passing in the form of a spark before contact of the poles. Prof. Daniell stated that "he had often seen sparks playing between the cells of his battery when they were approximated too much." This assertion was made prior to 1839, and Mr. Gassiot was of opinion that "Prof. Daniell labored under some error when he made this assertion," and in fact proves it so experimentally. Faraday went even so far as to assert that a spark would pass before contact, with a *single pair*. (Phil. Trans., 1834.) He afterwards admitted this to be an error, in the octavo edition of his Researches. He was led to review this opinion after Jacobi had proved that the current from even

12 pairs of plates in the most active operation would not pass through *one twenty thousandth* of an inch. Mr. Gassiot undertook a brilliant and very interesting series of experiments in October, 1839, to verify the striking distance. He was provided with the most powerful batteries, and an instrument called the micrometer electrometer, by which he could measure accurately the space of $\frac{1}{5000}$ of an inch. A battery of 150 pairs, which would give a "minute but brilliant spark on making contact with charcoal," would not pass it through $\frac{1}{5000}$ inch before contact. A Daniell's battery of 320 cells would not project a spark through this space, not even in *vacuo*. The current from a magneto-electric machine failed also to pass this space. It is evident that his machine was one of feeble power, as compared with that described by Prof. Page more than a year previous in Sill's. Journal. Mr. Gassiot then tried a water battery of 1,024 pairs, and even with this powerful battery there was not sufficient tension to pass $\frac{1}{5000}$ inch, although a Leyden battery could be charged by it to such an extent that it would discharge through the space of $\frac{6}{5000}$ inch. It required some minutes to accumulate this charge in the battery. Faraday was present at these experiments, and, from their very decisive results, Mr. Gassiot very naturally concluded that there had been some mistake made by those who had previously asserted the projection of the spark before contact. He afterwards found that his own failure to get the spark was simply owing to the fact that his battery series was not *sufficiently* extended. We are inclined to think that they were not well insulated also. The account of Mr. Gassiot's experiments was read before the Royal Society, December 19, 1839. On the 5th of February, 1839, Mr. C. V. Walker had proved by a micrometer arrangement that a "constant battery of 99 cells would not project the spark through the thinnest measurable stratum of air." (Pro. Lond. Elec. Soc., 1839, page 102, published 1841.) On the 17th of March,

1840, Andrew Crosse read before the Lond. Elec. Society a very interesting account of his wonderful water batteries, by far the most perfect ever produced. He there stated that "1,200 pairs give a *constant small stream* of the fluids between two wires $\frac{1}{100}$ of an inch apart before contact." Mr. Gassiot subsequently constructed a very extensive water battery of over 3,000 pairs and obtained sparks freely from its poles. Thus it came to be definitively settled that the galvanic battery *would* project a spark like a common electrical machine, and a close analogy, if not actual identity, was established between galvanic and static electricity.

THE MAGNETO-ELECTRIC CURRENT.

As soon as a magneto-electric current of any considerable energy was obtained from organized machines, attempts were made to obtain from this current, also, evidences of its electrostatic properties. The first machine was made by M. Pixii, of Paris, in 1832, and is described in Annales de Chemie, 1832, vol. 51, page 76. Before we commenced this investigation, we had supposed that the experiments with this machine were decisive as to the question of identity of magnetic and static electricity. Mr. Noad, in his Manual, vol. 2, page 697, remarks that, by Pixii's machine, "a gold leaf electrometer was made to diverge and a Leyden jar weakly charged." Many other authors have repeated the same statement. We have carefully examined the description of this machine by Ampere, who reported it to the Academy of Sciences, and fail to find these results. No mention is made of charging a Leyden jar, and the fact is stated that the machine "caused the gold leaves of the electroscope to diverge by the aid of a *Volta's condenser.*" Mr. Clarke states that the magneto-electric machine, made in imitation of Pixii's, exhibited at the Adelaide Gallery, London, "*did not* diverge the gold leaves of an electroscope ! Lond. Edin. Mag., June, 1837.

With Saxton's machine of 1833, which was a great improvement upon that of Pixii, no experiments for this purpose are reported. With Clarke's machine of 1835 and '36, which was similar to Saxton's, experiments of this kind were repeated, and we were left under the impression that Mr. Clarke had sufficiently decided the question of identity. We trusted to his statement in the Lond. Edin. and Phil. Mag., (vol. 9, page 264, Oct., 1836,) when describing the results of the intensity armature of his magneto-electric machine, "that it deflects the gold leaves of the electroscope and charges the Leyden jar." In the absence of any expression to the contrary, the inference was, of course, that he diverged the gold leaves of the electroscope *without* the aid of a condenser. It has come to light, however, that he first imparted a very feeble charge to a Leyden jar, and from this charged the electroscope. The jar, of course, takes the place of a condenser. Some person, over the signature J, makes the inquiry in the May No. (1837) of Sturgeon's Annals, page 327, "in what manner is a jar to be charged and the gold leaves of an electroscope to be deflected by a magneto-electrical machine?" This inquiry is answered in full in the next No. (page 407) by Mr. Clarke himself, who describes the manner in which he first charged the Leyden jar and then deflected the leaves of the electroscope. The description is accompanied with an engraving. There is a wide difference between these modes of charging the electroscope as respects the intensity of the electricity employed. Ampere says that the magneto-electric machine of Pixii "deflected the gold leaves of the electroscope by the aid of a Volta's condenser," so that we have no instance on record in which the gold leaves were diverged *directly* by the magneto-electric current, until this was done by Prof. Page with his improved magneto-electric machine in 1838. (Sill's Jour., vol. 34, page 166.) Fig. 8 represents the machine with circuit-breakers attached. We have before referred to this machine and its results. It is there stated that it "caused the gold leaves of the electroscope to diverge strongly without the aid of a Leyden jar or extended insulated metallic surfaces, and charges a Leyden jar at every touch." To charge a Leyden jar to such a degree as to be able to obtain from the *jar* indications with the electroscope, can hardly be accepted by itself as evidence of that degree of tension in the magneto-electric current, which would characterize it as possessing electrostatic properties. Perhaps, if this were the only indication possible to obtain, we might suppose an analogy or connection, but would not be willing to accept it as full identification. All the properties must be proved.

When the Leyden jar is to be charged, one terminal wire of the coil is to be in connection with the outer coating of the jar, and the other terminal to be carried to the knob of the jar, by an insulated handle, and the precaution usually observed of connecting the knob of the jar with the inner coating by a wire instead of a chain. The Leyden jar is, in fact, nothing but a condenser. It was well known that an extended series of galvanic battery (see Sturgeon's Annals, vol. 1, No. 1, page 40) would thus charge a jar, while it would not, by contact with a single pole, exhibit sufficient tension to diverge gold leaves, or project a spark through any distance. This Mr. Gassiot found to be the case with a battery of the immense power of 320 cells Daniell's constant battery. (Phil. Trans., 1840, p. 184.) He subsequently carried the galvanic series to such an extent as to exhibit electrostatic tension, which we have noticed elsewhere. The immense power of a condenser or Leyden battery, to absorb free electricity from a galvanic battery, is shown by these experiments of Mr. Gassiot. A water battery of 150 pairs, which would charge a Leyden battery of twelve-gallon jars sufficiently to fuse the point of a penknife and deflect the gold leaves of an electroscope, would not project a spark through $\frac{1}{5000}$ of an inch. He also found that a water battery of 1,024 pairs would charge a Leyden battery of nine jars to such an extent as to give a discharge through $\frac{6}{5000}$ of an inch, while this water battery would not of itself project a spark through $\frac{1}{5000}$ of an inch. It required nearly two minutes for the Leyden battery to condense or accumulate this charge. The best illustration of the correctness or propriety of such a test or standard of electrostatic identity, may be drawn from the Volta induction coil, when used with a condenser, as in the Ruhmkorff coil. The condenser is strongly charged by the primary coil, while it is not known that simple contact with the short primary wire has ever diverged the gold leaves of an electroscope, or projected a spark before contact; and, until one or the other of these conditions were fulfilled, physicists were not willing to accept the identity of the current of Volta electric induction with statical electricity. When one pole of a battery or one pole or terminus of an induction coil will, by simple contact with the cap of the electroscope, cause the gold leaves to diverge, there is evidence of free electricity, which escapes by transference or distribution, without the aid of co-operative induction from the other pole of the battery or terminus of the coil.

There is but one other record, so far as we can find, on this subject, prior to the announcement of Prof. Page's modification of the magneto-electric machine, and the electrostatic results obtained therefrom, to which we may briefly allude. (See Sturgeon's Annals, vol. 1, No. 1, page 80, Oct., 1836.) Mr. Sturgeon there states that he made a "visit to Mr. Rainey, a surgeon, at Maze Pond Borough;" "that he was pleased with his *pretty little** magneto-electric machine, which gave powerful and disagreeable shocks. It deflected the leaves of an electroscope and charged a jar to a low intensity." He says: "The divergency of the electroscope was not new to me, but the charge of a jar was perfectly so." He then describes the construction of a very extensive condenser, made of "three yards of varnished silk, coated with tin foil, and coiled upon a cylindrical nucleus of wood, an intervening ply of silk preventing the two coatings from touching one another." This was charged by the machine to a low intensity. Mr. Sturgeon says the divergency of the gold leaves was not new to him, but the charging of the jar was so, "as he had not seen it." He does not say that he had seen the gold leaves diverged before, nor does he describe how Mr. Rainey diverged them. But as he had a "*little machine*," which only gave "disagreeable shocks," it could not have been more powerful than Mr. Clarke's machine, and the unavoidable inference is, that his electroscope was diverged by the help of his Leyden jar, or his condenser—probably by the latter. This inference is strengthened, if not fully confirmed, by the fact before spoken of, that, subsequently, when a correspondent, in a letter to Mr. Sturgeon, as an editor, asks him how the gold leaves of an electroscope are to be charged by the magneto-electric machine, Mr. Sturgeon allows Mr. Clarke, in the next No. of the Annals, to answer for him in the manner before quoted, viz: by "first charging a Leyden jar." The readers of Sturgeon's Annals will not fail to observe the *readiness* with which he communicated all the information in his possession, and Mr. Clarke must be considered in this case as answering for Mr. Sturgeon.

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* The italics are ours.

In view of all the facts which we can bring to light upon this subject, we consider that—

Prof. Page was the first to prove the electrostatic properties of the magneto-electric current, as derived from the magneto electric machine.

A perusal of the description of his improvement in this machine, and its remarkable results, will show to what extent these properties were exhibited. (Sill's. Jour., vol. 34, 1838.) A separation spark of "half an inch in length" was obtained, and a truly projected secondary spark was seen to play between the segments of the pole changer, (about $\frac{3}{16}$ of an inch distance.) One of the most striking discoveries with this machine was the ignition of disintegrated conductors. A shred of iron filings, an inch long, was ignited and fused by the current. This is the basis of all the modern improvements in blasting, in which a disintegrated conductor is substituted in the fuse for a platinum wire. The penetration and ignition of conductors in the pulverulent condition is one of the most curious of all the results of the magneto-electric machine. A very small machine, incapable of igniting a platinum wire, will ignite plumbago, in the form of a pencil mark, through many miles of wire. It is stated, in a recent report of the Commissioner of Patents, that a "magneto-electric machine, contained in a box of a cubic foot in size, being worked by hand, in a telegraph office in Washington, exploded a cartridge of powder by this means in an office in New York, a distance of over 200 miles." The beautiful experiments with metallic powders, illuminated by the sparks from a Ruhmkorff coil, are all modifications of this discovery by Prof. Page; and he has recently announced that a spark of immense length can be taken from the conductor of a common electrical machine by passing it over a pencil mark drawn on a strip of dry paper.

Prior to the construction of Prof. Page's double machine, the only efforts to obtain an increase of power were by enlarging the magnets and coils. To this, of course, there was an early limit, but by the improvement no limit except the power necessary to revolve the armatures. He pointed out the way, and predicted in a most emphatic manner the electric light. The following quotation from a communication to Sill's Journal for January, 1839, under date of November 13th, 1838, by Prof. Page, is not without interest. "The avenue, then, to an indefinite power, is too obvious to escape notice. Increase the number of pairs of magnets, extend the series of armatures on the same shaft, or in any way in which they may be brought to bear on the same terminal poles, and I hazard nothing in the assertion that, for the same prime cost, and contained in the same space, a magneto-electric machine can be made of equal power to a galvanic battery of one thousand pairs of plates. It is evident that there will not be that rapid diminution with the extension of the series which obtains in the galvanic arrangement, for the whole route of the current will be through solid conductors. Nothing but the want of means has restrained me from erecting a magneto-electric machine which, I feel confident, would rival the largest galvanic battery in existence. *The arch of light would be obtained by disposing one set of armatures at right angles to the other, so that, while one gave a diminishing current, the other would afford a current in the same ratio. While one set was in the neutral plane, the other would be at the point of strongest action.*" This principal of multiplication and concentration has been carried out in all the large machines used in the arts for electrotyping, illuminations, blasting, and telegraphing. So impressed was Prof. Page with its practical importance, that in 1843 he applied to Congress for leave to take out a patent for his improvements. The petition was refused, Prof. Page being an officer in the United States Patent Office, and debarred by law from taking a patent, Congress declined to make an exception in his favor. Some idea may be formed of the advanced condition of this machine in his hands, in 1838, by referring to the experiments of Gassiot, in London, in October, 1839, (Phil. Transactions, 1840, page 185,) when he failed to get a spark from a magneto-electric machine, through $\frac{1}{5000}$ of an inch. Mr. Gassiot was remarkable for his munificence in the preparation of apparatus for experimental purposes, and we presume employed the best magneto-electric machine to be had in London at that time.

THERMO-ELECTRICITY.

For many years after the discovery of the thermo electric current, fruitless attempts were made to obtain a spark from it. This seemed to be wanting to establish the identity between this and galvanic electricity. The spark was first produced by Professsor Page in August, 1836, and the spark and shock were both produced by him December 2, 1836. (Sill's Journal, vol. 33, page 118.) The spark was obtained afterwards in Europe by Linari & Antinori in Italy, and announced December 13, 1836. The discovery admitted this species into the electrical family; but it is only within two or three years that a thermo-electric current of any magnitude has been obtained, and now, in the hands of Moses G. Farmer, of Boston, it is made to perform the work of galvanic batteries of considerable size. As a means of operating the Ruhmkorff coil, the thermo-electric battery is very efficient, convenient, and elegant, and thus we have advanced to that stage of improvement, that the once invisible current leaps before our eyes in brilliant flashes, and ranks as a rival with the highest sources of static electricity.

THE INDUCED CURRENTS.

When Faraday discovered the induced current in 1831, the current of his secondary wire had less intensity than that of the primary wire, and as he did not obtain even the sign of a spark, it was not to be expected that his mind should have been directed to any efforts to prove analogies between the induced current and static electricity. In the accounts of subsequent experiments of Dal Negro, Professor Henry, M. Masson, and Dr. Neef, which we have described in Chap. I, this subject was not mentioned. Neither of these philosophers went beyond the primary current in their investigations. In 1834 Faraday obtained a feeble spark from a secondary wire, (which was actually shorter than the primary wire,) but this appearance excited no particular attention, and, instead of being regarded as an indication of intensity by Faraday, or as a current in any way differing in condition or powers, he concluded that the two currents, viz., primary and secondary, were equivalents, which, in fact, they were, as his two circuits were of equal capacity. He thus expresses it: "The strong spark in the single long wire or helix, at the moment of disjunction, is therefore the equivalent of the current which would be produced in a neighboring wire, if such second current were permitted"—that is, if the ends of this neighboring wire were connected.

As soon as the secondary induced current was exalted to one of intensity by Professor Page, he turned his attention at once to the identification of this current with static electricity. In his communication to Sill's Journal, dated Salem, Mass., May 12th, 1836, it is stated that a "two-quart Leyden jar was charged by the secondary circuit so as to give shocks." (Sill's Journal, vol. 31, page 140.) In his next communication, dated April 24, 1837, it is stated that "vivid sparks pass between charcoal points in the induced circuit, provided they do *not quite touch.*" (Sill's Journal, vol. 32, page 355.) In his unpublished communication to Sill's Journal, dated December 2, 1837, endorsed by the editor as received December 8, 1837, he states as follows: "I have at last succeeded in charging a Leyden jar by the action of the spiral in connection with a *single pair* of plates." This subject is again introduced in a communication, (Sill's Journal, vol. 34, page 166, 1838,) and in the same vol., page 372, in describing a powerful coil, it is stated that an intense light was produced between charcoal points in the induced circuit, a Leyden jar was charged, and that the induced current was sufficiently intense to pass from one person to another through the floor. Again, in the description of his compound-magnet and electrotome, Fig. 2, published in Davis' Manual, November, 1838, as we have before quoted, it is stated that the "induced current passed between points *before contact*, deflected the gold leaves of an electroscope, and charged a Leyden jar." Again, it is stated by Davis, of another of Professor Page's coils, that the induced circuit "produced a beautiful light between charcoal points held almost in contact. Water was decomposed by using Wollaston tubes, and the platinum points were luminous. During the decomposition, sharp, ticking sounds were produced, audible at the distance of eighty feet. A Leyden jar was charged by simple contact of its knob with one terminal of the induced circuit, so as to give shocks. A gold leaf electroscope was readily affected by touching its cap with a wire fixed in either terminal cup of the secondary circuit, the leaves exhibiting considerable divergence, and without the aid of a condenser;" and, finally, it is stated that the "wire must be well insulated from the hand in which it is held, or the electricity will be conveyed off and no accumulation be obtained." What more do we require? what more could the most rigid exactions of science demand, than these results, as proof of the complete identification of the induced current with static electricity? It must be borne in mind that all these developments of intensity were produced by the use of Professor Page's spark-arresting circuit-breaker of 1836. No measurement of the striking distance was made; but the simple fact was discovered that a spark was projected through discernible space, *before contact*, and this was witnessed by hundreds of persons who purchased the apparatus of Mr. Davis. The electrostatic properties of the coil were thus positively settled, and the apparatus was made, advertised, and sold for the very purpose of exhibiting phenomena upon which identification was to be proved. It is true that a part of this last quotation is from the edition of Davis' Manual of August, 1842, pp. 183, 184, but it is only a repetition (with the exception of the sounds and luminosity during decomposition) of what was stated in 1838 of the compound magnet and electrotome, accompanied with particular instructions as to the manner of conducting the experiments.

In regard to the spark-arresting circuit-breaker announced in 1836, Prof. Page communicates the following, in the early part of 1838, (Sill's Jour., Vol. 34, No. 1, page 166:) "I have some time since shown that the shocks and decompositions produced by the secondary current of flat spirals and helices, in connection with a single pair of plates, were greatly increased if the surface of the mercury or *solid conductor*, from which the circuit is broken, be covered with pure water or naptha. I have since found that oil* gives a far greater increase than either." Then follows the rationale; but as it is rather more fully given in the succeeding volume of the Journal, page 256, we quote the latter. In the communication on the compound magnet and electrotome, dated November 13, 1838, preparatory to its description, the following experiment is given: "Place a straight electro-magnet upon a large flat spiral of copper, in the direction of a radius of the spiral. When the spiral is connected with the battery, the magnet becomes charged, and a secondary current in its wires is the consequence. Break the battery connection with the spiral, and examine by the common tests the power of the secondary from the magnet; again, break the circuit from mercury covered with oil; and the secondary from the magnet will now be found stronger than in the first case. When the circuit is broken over clean mercury, the secondary, flowing through the heated vapor and air, acts as a closed circuit to prolong the magnetism of the spiral, and thus prevent a sudden influence upon the magnet. When the mercury is covered with oil, the secondary of the spiral is arrested, and the magnetism, suddenly ceasing, exerts its whole influence upon the magnet; or rather, the magnetism of the bar ceases with that of the spiral. The same phenomenon is well illustrated by the electro-magnet alone, where the fine wire is independent of the large." The same subject is again alluded to on the succeeding page, and again in volume 37, page 276, July 23, 1839, making the sixth time in which the application of this principle had been brought forward in so many distinct publications. Notwithstanding the peculiar advantage thus derived in the development of secondary currents and augmenting their intensity, no one in Europe seemed to have taken any notice whatever of its value; and for a period of more than three years after its first announcement by Prof. Page, we find no mention whatever of any attempts on the part of the European philosophers or experimenters to obtain electrostatic results from the secondary current. During that period a very great number of induction coils and circuit-breakers were announced, but no importance or interest seems to have been attached to this branch of the subject. We had the Masson coil, the Neef coil, the Callan coils, the Sturgeon coils, the McGauley coil, the Dr. Bird coil, the Lockey, the Nesbitt, the Clarke, the Roberts, the Bachhoffner, and many other coils, all represented as being very potent in giving shocks; but, beyond the intensity required for this purpose, not a single inquiry is recorded.

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* Sperm oil was generally used. Olive oil will answer.

In October, 1839, Mr. Gassiot, of London, undertook to satisfy himself as to the striking distance of galvanic batteries by experiments, which we have given in detail at the beginning of this chapter, and also tested the power of the secondary. (Phil. Trans., 1840, page 188.) He used the magnetic-electric multiplier of Prof. Page, and obtained sparks between two platinum points of $\frac{1}{100}$ of an inch, and also a stream of sparks between charcoal points $\frac{1}{300}$ of an inch. A Leyden jar was charged sufficiently to deflect the gold leaves of the electroscope. These indications were considerably below those already described as obtained from the Page coils, but were, nevertheless, decided and positive. It will be remembered that in Prof. Page's experiments *shocks* were obtained from the Leyden jar and the gold leaves of the electroscope made to diverge without the aid of a Leyden jar or a condenser. If Mr. Gassiot had manipulated the multiplier according to the directions of Prof. Page, (Silliman's Journal, vol. 34, page 372,) by breaking the circuit by mechanical force at the moment the armature required the maximum of force to carry it beyond the magnetic poles, he would have realized much better results, and still greater advantages might have been reaped if he had covered the mercury of his circuit-breaker with some non-conducting liquid. Before describing the experiments with the coil, he states, p. 187, that "his attention had been called to similar results obtained by Faraday, (see his ninth series § 1090") evidently meaning that Faraday had obtained the *striking distance*—that is, a secondary current projected in the form of a spark before contact. In this we are convinced that he was entirely in error. Faraday's experiment is as follows: A primary helix of copper wire, 96 feet long and $\frac{1}{24}$ of an inch thick, was wound upon a pasteboard tube, so as to admit of the insertion of a bar of iron. Another secondary wire of the same size, and 94½ feet long, was partly interwound with the primary and partly exterior to it. The wires were naked and their convolutions separated by winding a string between them. The superposed layers were prevented from contact by a strip of calico. The battery consisted of one pair of cylindrical plates, the zinc plate being eight inches high and four inches diameter. With this apparatus he states that, when the "primary wire was connected with the battery and the ends of the secondary wire disconnected, the primary gave a good spark at the place of disjunction." "When the ends of the secondary were connected, no spark, or one scarcely visible, was produced by breaking the primary circuit." "Then, again, when the ends of the secondary helix were held so nearly together that any current running round that helix should be rendered visible as a spark, a spark was obtained instead of appearing at the disjunction of the primary helix." "These effects were reproduced by two extended long wires." It must strike any one familiar with such experiments, that, with such an apparatus as was here employed, a tension spark, through discernible or measurable space, was out of the question, or, in other words, that the means were entirely inadequate to produce a spark before contact. With the extended wire the breaking of the circuit would not even produce a shock with the primary wire, except in the mouth with two silver plates, (§ 1064.) The insulation of both wires was of the most imperfect description, and not the slightest indication of shock was obtained from the secondary circuit, though it should have been competent to produce very powerful shocks if its intensity had been sufficient to project a spark. The description, in fact, bears its own refutation of any such construction. When the secondary circuit was closed, the spark of the primary disappeared, and in the case of the supposed spark before contact, it "*also disappeared.*" Now, if the spark of the secondary passed *before contact,* the spark of the primary should *not* have disappeared, but there should have been a considerable spark at the disjunction. This is too plain, as a matter of principle and matter of *fact,* to be disputed. The spark seen was merely the spark of *ignition.* Faraday himself explains very satisfactorily this spark of ignition, (§ 1074.) After describing an electric spark as "the bright appearance of electricity passing suddenly through an interval of air or other bad conductor, he says: "The Voltaic spark, especially between one or a few pairs of plates, is due to the ignition or even combustion of conducting matter," and that the "spark often appears to pass before contact, when it is only a case of ignition by the current, contact being previously made, and it is perfectly analogous to the ignition of a fine platinum wire connecting the poles of a Voltaic battery." It was such a spark, and no other, which was produced in this case. We have already mentioned the fact that Faraday had asserted (Phil. Trans. 1834, § 957,) that a "spark passed before contact with a battery consisting of only a *single pair* of plates," and that after Jacobi disputed this (Phil. Mag., December, 1838, p. 401,) proving that a spark even from 12 pairs would not pass the $\frac{1}{20000}$ inch, he acknowledged his error, considering the spark to be one of ignition *after* contact. As we shall presently see, M. M. Masson and Breguet failed to get a spark through the air, even with their powerful coils, although their experiments were regarded by many authors as conclusive on the question of electrostatic identity. Mr. Gassiot himself, in this communication, alludes to several powerful galvanic batteries which gave this spark on the completion of the circuit, which, nevertheless, would not project a spark through $\frac{1}{5000}$ inch. This apparent spark is best seen when one of the approximated conductors is pointed. It is often much increased by the ignition of adherent loose atoms of metal. Mr. Gassiot was undoubtedly the first among Europeans to observe the projected spark, and the electrostatic powers of the secondary coil, although every author who has written upon the subject has given the credit of this discovery to Messrs. Masson and Breguet, of France. Even Mr. Noad has overlooked the claims of his own countryman, as compared with those of the two above named philosophers.

The memoir of Masson and Breguet was presented to the Academy of Sciences 24th August, 1841, but was not published till 1842. We have before referred to their experiments, and expressed the opinion that they were not entirely satisfactory, although Du Moncel and Becquerel both assert that they were the first to establish the connection between the secondary current and static electricity. One says their wires were "badly insulated," and the other that they were "suitably insulated." All authors, with the exception of De la Rive, agree in stating that they used only a primary coil. If this be so, we are at a loss to understand the meaning of the following passage in their communication. (Annales de Chime, 1848, Vol. 4, p. 150:) "En substituant le courant d' induction a l'extra courant, le phenomene lumineux se produit encore completement. Ce fait prouve qu'on peut induise un courant dans un fil ouvert, et que l'induction est un phenomene d'electricité statique." Again, in summing up, the 5th conclusion is as follows: "La lumiere électrique produite dan le vide par des extra-courants, ou des courants d'induction, presente tous les caracteres assignés a la lumiere electrique produit dans les memes circonstances, par des machines ou des bouteilles de Leyde." These remarks certainly imply the passage of the spark in vacuuo from the secondary as well as the primary circuit. It is true, these allusions to the secondary current are somewhat incidental, being the only mention made in the course of a long communication of over twenty pages, nearly the whole of which is devoted to experiments with the extra-current, or that from the primary coil. Their apparatus was very poorly calculated to prove their conclusions, as they had a secondary circuit of the same length and size of wire as the primary circuit, and their extra-current must have possessed greater intensity than their secondary. They used a coil of 1,300 meters of wire of 2½ millimeters thickness, divided into two lengths of 650 meters, and wound up side by side, the wire being covered with cotton, without varnish or insulating cement of any kind. Their only induction current, therefore, was from one of these two lengths of wire, and the central opening of their coil was over six inches in diameter, so that when a bar of soft iron was introduced, it actually retarded and diminished the secondary currents. They were certainly much behind the times in the selection and construction of their induction apparatus; and from the inadequacy of their means to manifest high intensity by their secondary circuit, we are willing to accept the authority of Du Moncel and Becquerel, that their results were produced by the extra current or primary circuit. In passing, we remark that Faraday first used the term *extra current* to designate the secondary current from a primary coil. Masson and Breguet failed entirely in getting any spark through the air, though they obtained one of two millimeters length in vacuuo. They charged a condenser, and from that deflected the gold leaves of the electroscope. They state that, after the sparks had passed, while the circuit-breaker (one of the mechanical class) was in operation, they "gradually separated the points until their distance was two centimeters," (little over $\frac{3}{4}$ inch,) and the light still played between them. As they used eight and more pairs of Daniell's battery, a considerable portion of this light was undoubtedly due to the passage of the battery current itself. Their striking distance in vacuuo must be taken as that beyond which the current would not pass before they commenced to separate the points, viz: 2 millimeters, (about $\frac{1}{13}$ of an inch.) If these had been the first and only indications obtained to prove the electrostatic powers of the coil, they might have been justly regarded as affording some proof. But, in point of magnitude and decisive character, they must be regarded as decidedly inferior to those before obtained by Mr. Gassiot and Prof. Page. It is very singular that Mr. Gassiot obtained no increase of length of spark in vacuuo. It must have been that his exhaustion was not good for a coil that will give any perceptible length of spark in air, will give a very considerable increase of length in vacuuo. Thus, Sir Humphrey Davy says that his battery, which "projected a spark $\frac{1}{40}$ inch in air, projected through half an inch in vacuuo." Twenty times the distance! We get a greater ratio with the secondary current on account of better insulation. Mr. Gassiot's coil gave by actual measurement a projected spark of $\frac{1}{100}$ inch, (a division of space quite discernible to good eyes,) while Masson and Breguet's coil gave no spark in air, and one of 2 millimeters in vacuuo. The spark of Prof. Page's coil was not measured, but is described as a stream between charcoal points not in contact. As, however, the other electrostatic indications considerably exceeded those of Gassiot, we are warranted in the inference that the projected spark was longer. In order, however, to settle this point beyond all doubt, we have recently made trials of the *original* compound-magnet and electrotome made for Prof. Page in 1838, and find that exactly in its primitive condition, with a single pair of Grove's battery, it gives sparks from $\frac{1}{40}$ to $\frac{1}{16}$ inch in length, and that it lights vacuum tubes $4\frac{1}{4}$ inches in length. This coil is represented by Fig. 2, corresponding exactly to the description in Sill's Journal, vol. 35, page 258, and in Davis' first Manual, Nov. 1838, with the exception only that, in the description in Sill., the iron hammer piece is described as a "cylindrical piece, the length of whose axis is greater than its diameter." The disc of the McGauley circuit-breaker was the worst form for attraction. It was discovered by Prof. Page, in 1838, that a piece of soft iron in the form of a disc could be presented to the pole of an electro-magnet in such a manner as not to be attracted in the least. (Sill's Journal, vol. 35, No. 3, page 265.) The advantage, therefore, of the cylindrical or elongated piece over the disc or ball, is obvious. The spark-arresting circuit-breaker was used, and the following certificate is introduced merely as corroborative of our statement.

We, the undersigned, have seen repeated trials in the United States Patent Office of an old* induction coil of small size, 7 inches long, 2 inches in diameter, certified to us by Prof. Page as the original instrument, called the compound magnet and electrotome, made for him by Daniel Davis, of Boston, in 1838. The apparatus corresponds to the description given in Sill's Journal and Davis' Manual in 1838, and is worked by breaking the circuit from mercury under some non-conducting liquid. With two pairs, Groves', a stream of short sparks, with distinct sounds, is obtained from the secondary coil, varying from about one-thirtieth to one-sixteenth of an inch in length, and it illuminates successfully a small vacuum Geissler tube 4¼ inches long. A condenser connected with the coil did not improve the results in the least. It is a Ruhmkorff coil on a small scale, and demonstrates the electrostatic character of the secondary current as conclusively as coils of much larger size and power.

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* It is a very remarkable fact that this and one other electrostatic coil, with the rasp and vibrating armature electrotome attached, were the only

We have also examined a drawing of an induction coil, called compound-magnet and electrotome, dated May 4th, 1838, certified to us by Prof. Page, as made by him at that time, which has much better provisions for insulation than the one we have seen tried. The coils are secured to the top of a low wooden pillar three inches high, and the entire circuit-breaker, with its mercurial cups, and also the cups for the secondary coil, are fixed upon a thick strip of mahogany lying over and upon the coil, and extending nearly its whole length. Prof. Page states that he desired to have

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instruments of value saved *entire* from the wreck of Prof. Page's collection of philosophical apparatus destroyed by the United States soldiers in the spring of 1862. The United States soldiers encamped around Washington believed at that time (and in this they were not far from the fact) that most of the residents in the country outside of the city were secessionists, and lost no opportunity of visiting their displeasure upon them. On this occasion, mistaking their man, as Prof. Page was a Government officer at the time, a raiding party of soldiers got into an outbuilding where his extensive philosophical apparatus was kept, and destroyed the entire collection, the accumulation of thirty years' labor. No redress has been made.

one made after this plan, but the instrument-maker thought it would look very clumsy, and its manufacture therefore was not urged. The plan is much more philosophical, especially in reference to insulation of the outer or secondary coil, than the one before us, and, had it been carried into operation, would, undoubtedly, have given better results. The laying of the secondary coil for its whole length *directly upon* the baseboard of the machine to which are attached all the cups for connections, and all the brass mountings for supporting the cut-off, and for securing the coil as in the one before us, is certainly not compatible with good insulation of the secondary coil. The plan in the drawing avoids this defect. Fig. 10 is a correct copy.

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In a communication to the London Electrical Society, dated 17th September, 1841, Mr. Gassiot describes some experiments with an immense secondary coil, and with a powerful battery. The size of the battery is not given. His secondary coil was 12 miles long, of No. 30 copper wire, well covered with cotton and shellac varnish. With this coil he obtained sparks in air, but does not give their length. "In the flame of a spirit lamp he obtained sparks three quarters of an inch in length." From this we infer that the sparks in air were not less than ¼ inch in length. (Pro. Lond. Elec. Soc., 1843, page 119.)

Mr. Hearder, of England, in describing a coil of his (Lond. and Ed. Journal, 1856,) as an improvement on Ruhmkorff's, says it gave sparks three inches long in air, and nine inches long in the flame of alcohol. This difference of one-third we have verified by experiment.

From the announcement of these experiments until 1851, no advances seem to have been made in Europe in the way of augmenting the power of the secondary current. During that time, however, the Page coils in the United States were manufactured and sold extensively to schools, colleges, and individuals, and many of them upon an enlarged scale. All of these projected a short spark, and some of them gave sparks $\frac{1}{10}$ of an inch. These facts are stated under oath by several witnesses, whose affidavits are attached to a printed memorial laid before Congress in January, 1866. These witnesses are philosophical instrument-makers who have made and sold the Page coils. N. B. Chamberlain, a maker of instruments in Boston, since 1831, states that as early as 1842 he obtained, with the Page coils, sparks, discharges of Leyden jars, and on one occasion obtained flashes of light through a vacuum tube *twelve or fifteen* inches in length. His son, H. B. Chamberlain, fixes the length of spark at $\frac{1}{10}$ of an inch. Mr. Grant, instrument-maker, fixes the sparks of the Page coils at $\frac{1}{10}$ inch, and testifies that in 1842–3 he "enlarged the Page coils, using for the secondary coils several miles of fine wire, and that he obtained sparks *half an inch* long, and performed other electrical experiments. That he made a large number of such coils; and that when the Ruhmkorff coil was first announced in this country, it was "no novelty," and was not so large or so efficient as the Page coils of his own make of some years before. His coils were four to six inches diameter and fourteen to eighteen inches in length. With all these facts in evidence and of record before us, we can readily understand and appreciate the remark of the editors of Silliman's Journal, appended to the communication of their foreign correspondent, Prof. J. Nickles, dated Paris, September, 1852, announcing the

Ruhmkorff coil. The remark is as follows: "The name of Dr. C. G. Page should here be added. There are many points of resemblance between the apparatus of M. Ruhmkorff and the Compound-Magnet and Electrotome of Dr. Page, whose apparatus appears to be but little known in Europe. See this Journal, vol. 25, page 252, 1839.—*Editors.*" (Sill's. Jour., vol. 15, page 114, 1853.) This remark of the editors, prompted by a desire to do justice, was appropriate and well-founded. It is probable that the apparatus referred to was not much known in Europe. Silliman's Journal circulated in Europe more among naturalists than physicists or electricians, and comparatively few of Dr. Page's communications were republished in European journals. But whether it was known or not, we regret to find among scientific authors so much national favoritism in making up their records. Science is as broad as the world, and those who cultivate it should cherish universal respect for the claims of their co-laborers wherever found. National or sectarian preferences should never be permitted to give undue prominence to any discoverer or inventor, nor, in making up the history of any subject, to permit the *suppressio veri.* Of this latter ingredient there is altogether too much to be found among electrical authors. We have proceeded in this work upon the largest possible examination and admission of the claims of every contributor to our branches of electrical science, adopting the motto of "credit to whom credit is due." A single instance will suffice to illustrate this national bias which we deprecate. Mr. Noad, in his Inductorium, page 26, remarks as follows: "Various contrivances have been adopted for breaking and renewing battery contact, some of an automatic character, others requiring manual assistance. Dr. Bird was the first, in this country at least, to employ the permanent magnet to effect rupture of contact; this he did by," etc. The implication here is, that Mr. Noad had not investigated the subject beyond the limits of his own country, or else that he was aware that the same thing had been employed in some other country. He gives a full description of the apparatus, taken evidently from Dr. Bird's own account of it in the Lond. and Ed. Phil. Mag., January, 1838, at the conclusion of which Dr. Bird himself gives Dr. Page full credit for originality in the invention of the identical circuit-breaker. This is a clear case of the *suppressio veri*, without actual *tort.* Of the latter wrong we have already proved several striking examples, whether prompted by national pride or ignorance of the facts, we express no opinion. There is a shadow of excuse for a failure to recognize facts that are only to be learned from foreign languages, but as between English and American authors there is no ground for extenuation. A very remarkable case of misplacement of title to originality is to be found in the following article from the Scientific American of December 24, 1864, page 401:

> **"In a recent number of the Scientific American, it was stated that Professor Tyndall, in a late lecture before the Royal Institution, had attributed to Mr. Joule, of England, the discovery of the disturbance of Molecular forces by magnetism, when, in fact, the discovery was made, and published in Silliman's Journal, by Professor Charles G. Page, of Washington, several years before the experiments of Mr. Joule. Turning to Professor Tyndall's book of lectures on "heat as a mode of motion," we find him chargeable with another anachronism, more decidedly erroneous in the record of scientific discoveries. The discovery of the vibration of "Trevelyn's bars," by galvanism, and also the continuous rolling of metallic cylinders upon rails, by the same agency, is ascribed by Professor Tyndall to George Gore, Esq. Mr. Gore first made his experiments before the Royal Society, June 3d, 1858, and published the same in the Philosophical Magazine, June, 1858. More than eight years before, these same discoveries were announced by Professor Page, in Silliman's Journal for January, 1850, together with illustrations of some interesting applications in the way of the "*physique amusante*" growing out of these discoveries."—*Editors.***

If we are right in our conclusions, drawn from historical facts, in awarding so many claims to Professor Page for original discoveries and in inventions in induction and induction apparatus, it is more than strange that his name has not been mentioned in connection with the electrostatic coil by any European writer. As an example to show how completely everything acccomplished by him prior to 1840 was ignored or overlooked by European authors, the following is quoted from Noad's Inductorium, 1866, page 33. "Up to about the year 1842, the only object sought by makers of electro-magnetic machines would seem to have been the production of shocks and the regulation of their intensity and frequency." "It was M. Masson who, in that year, first directed attention to other static phenomena which the instrument was capable of developing." We have already adduced enough in this treatise to furnish a thorough refutation of this opinion. The compound-magnet and electrotome, Fig. 2, advertised by Mr. Davis in 1838, was an instrument for scientific observation upon the electrostatic powers of the secondary current, rather than for any other purpose. The shock from the secondary coil was entirely too powerful for convenient use for medical purposes, and the magnetic core, consisting of a bundle of wires, was *fixed* in the coil, and not movable or adjustable, as it was in the machines designed for giving and regulating shocks. The "double helix and electrotome," and the "separable helices" were specially advertised by Davis in 1839 for illustration and instruction as to the varied properties of the secondary current. They are of large size, and the prices of the instruments were $20, and $25. We cite these prices because they in fact convey some idea of the character and design of the instruments; for in the same catalogue Davis advertised two special forms of instrument for shocks or medical purposes, the price of which were $6 and $8. Fig. 7 exhibits one of them, which will be recognized as Page's revolving armature. The report of the Committee of the Massachusetts Charitable Mechanic Association, dated September 23, 1839, which is embodied in this catalogue of Davis, commends in high terms these particular instruments, giving their names, and also the skill of Mr. Davis and the labors of Dr. Page. It further states that "many of these instruments had been sent to Europe," and we must, of course, infer that the printed instructions had been sent with them. The description which Davis gives of the performances of these instruments would pass well for a short treatise upon a Ruhmkorff coil as it appeared in Europe more than twelve years afterwards, and is in striking contrast with the views entertained by Mr. Noad, as above cited.

A brief review of the above record shows conclusively that Prof. Page was the first to show that the secondary current was possessed of electrostatic properties of *any* kind, and that he was the first to prove its idenity with static electricity by an exhibition of *all* those properties of attraction, induction, and tension necessary to a full identification. These were the shock, the projected sparks, the charging of an electroscope without a condenser, and the charging of a Leyden jar so as to produce shocks therefrom.

That Mr. Gassiot, in England, was the next to obtain these indications, though in a more feeble degree.

That Messrs. Masson and Breguet, in France, afterwards obtained some of these indications, failing to obtain that which was of paramount significance, viz., the projected spark in air.

That about the same time, or perhaps a little later, Mr. Gassiot obtained a higher degree of tension of the secondary current than in any former experiment, producing sparks ¼ inch in length in the flame of a spirit lamp.

That Prof. Page was the first to discover the principle of increasing the electrostatic powers of the secondary by the sudden arrest of the primary current, and the means by which the same could be effected.

In the year 1851 M. Ruhmkorff, a skillful instrument-maker of Paris, made a powerful coil, by which he obtained short sparks in air, and the usual evidences of high electrical tension. We do not find in Du Moncel, or Becquerel, or Noad, any mention of the length of this spark, although we think we can approximate it. The coil was made with a primary of copper wire of 2 millimeters diameter and a secondary circuit of very fine wire $\frac{1}{3}$ millimeter in diameter and about six miles in length. Special attention was paid to the insulation of the secondary wire, which Du Moncel says was "drowned" in shellac. It is stated also that he made the coils of greater axial length than those of Masson and Breguet, which we have before seen were particularly awkward and unfavorable in their proportions. Du Moncel, Becquerel, and Mr. Noad, speak of his use of a bundle of wires for the magnetic core as if it were a meritorious application on the part of Ruhmkorff, which we are at loss to comprehend, seeing that the bundle of wires was thus used by Dr. Page and Mr. Gassiot, and by almost every coil-maker after its discovery in 1837. For a circuit-breaker he adopted the McGauley hammer, which, as we have before seen, was adjustable only as to distance between the attracting points.

We have not been able to find any public record of all the particulars of this coil and its performances, made at or near the time of its execution, and have relied mostly on the 1856 editions of Du Moncel's and Becquerel's Treatises on Electricity and Magnetism. Soon after the experiments of Ruhmkorff were made, Fizeau suggested the connection of a condenser with the primary coil as a means of increasing the statical power of the secondary current. Its adoption by Ruhmkorff, in connection with his coil, at once exalted its power so as to produce sparks in air one and a half centimeters in length, and in vacuuo a luminous arc more than a decimeter in length—about four inches. It illuminated the electric egg in a beautiful manner, giving a red light about the positive pole, and a blue light at the negative. Du Moncel says in one place that the spark was nearly two centimeters in length; but, in summing up the several properties of the secondary current, he fixes the length of the spark at one and a half centimeters. Becquerel says the length was one centimeter—a little less than $\frac{4}{10}$ inch. These were the sparks attained by the aid of Fizeau's condenser. Now, according to the usual rate of decrease in the length of spark in such large coils, by the withdrawal of the condenser, we shall be able to find the length of spark obtained by Ruhmkorff. According to Mr. Noad, (Inductorium, page 42,) Mr. Ladd's coils are so fitted that the condenser may be detached at pleasure. "When this is done, while the sparks or flashes, four inches in length, are leaping between the wires of the discharger, they immediately cease, and the terminals require to be brought within half an inch of each other before their thread-like sparks can be made to pass between them." This accords with our own observation in certain cases. The spark without the condenser is here one-eighth of the spark with it. Taking .60 inch as the maximum of Ruhmkorff's spark with a condenser, we may be safe in deciding that they were not over $\frac{1}{10}$ inch without it, probably less. This is decidedly an inferior performance to the coil of Mr. Grant of 1842, which gave $\frac{1}{2}$ inch sparks without a condenser, inferior to Gassiot's twelve mile coil of 1841, which gave $\frac{3}{4}$ inch sparks in the flame of a spirit lamp without a condenser, and very little better than the original electrostatic coils of Prof. Page of 1838–9, as used with the spark-arresting circuit-breaker. In what, then, we ask, consisted the peculiarity of the coil made by M. Ruhmkorff, distinguishing it from all others to such an extent that it should bear his name? Was it in increasing the length of the axis? This we have seen was not new. Was it in the use of the bundle of wires in place of the solid bar for the magnetic core? This we have seen was not new at the time. Was it in insulating the fine wire carefully with shellac? We have already, in the first part of this work, quoted Prof. Callan's instructions on this point in 1837, and it is not amiss to repeat them here, in part, at least. "However great the magnetic power may be, however long or fine the wire, however small its distance from the iron, and however perfect the coiling, the intensity of the electric current will be but trifling if the insulation be bad. When high intensity is sought for, the covering of the wire will not be sufficient to insulate each coil from all the other coils: a coat of sealing wax varnish, or of some non-conducting cement will be necessary." Had the coils made by Prof. Callan been provided with the bundle of wires in place of the solid magnet, he undoubtedly would have witnessed some electrostatic results in the course of his experiments, for he employed very long and fine wires. Mr. Gassiot also states that his twelve-mile coil of 1841 was well insulated with shellac varnish.

Finally, was the merit of the Ruhmkorff coil to be found in the circuit-breaker, or in any other feature, or in the combination of all the above enumerated features? We answer, in neither of these conditions. The circuit-breaker was that in common use at the time, for induction coils, and as to instrument, considered as a whole, the Page coil of 1838 contained all the parts of this coil, and exhibited all its properties. The secondary wire was very much shorter, and of larger diameter in the Page coil; and although it was stated that the fine and coarse wire coils were "entirely separate and insulated," yet it is probable the insulation of the Ruhmkorff coil was better; but, as we have already seen, it was no better than many others which preceded it, and the coil was actually of less power than Gassiot's twelve-mile coil.

THE CONDENSER.

It was the discovery of the action of the condenser upon the secondary current by Fizeau that awakened attention and gave a new impulse to the use of the induction coil. In 1853, Fizeau, while investigating the subject of induction, found great annoyance from the irregular action of the primary current. When the sparks of the circuit-breaker were brilliant, the intensity of the secondary was diminished, and when some obstruction occurred to diminish the sparks, the secondary was increased. The irregular action arose from the burning away of the points of contact by the primary or extra current. He sought, therefore, to diminish or absorb this current, by interposing a Leyden jar or a condenser. By connecting the plates of the condenser with each side of the interrupter or circuit-breaker, he found at once that the sparks were diminished, while those of the secondary circuit were doubled in length. (Comptes Rendus, vol. 36, p. 420, 1853.) He also suggested the convenience of placing the condenser beneath the machine, and alluded to the effect of a long fine wire in suppressing the extra current. Ruhmkorff soon applied Fizeau's condenser to his coils, and exalted the intensity of the secondary so as to increase the spark from ⅛, or thereabouts, to a little over half an inch in length. In the first part of this work, the order in which the statement is made would lead to the inference that the half-inch spark was obtained without the condenser. It is here stated correctly. And here we have the solution of our question. From the fact that he was the first instrument-maker to adopt the Fizeau condenser, his coil was considered the starting point, and the basis of all the splendid improvements made by others since the year 1856. Although his coil was made in 1851, yet, notwithstanding the advantages of the Fizeau condenser, we do not hear of any improvement of note in the power of the coils until the subject was taken up by Mr. Hearder, Mr. Ladd, and Mr. Bentley, in England, and Mr. Ritchie in the United States. The improvements were so rapid during 1856 and 1857, that the secondary spark was increased from ½ or ¾ inch to fifteen inches. This improvement was, as we have seen in Part I, made by Mr. Ritchie, of the United States, in 1857. We have also given there a detailed account of the various improvements, and the times of making them. So far as we can learn, it was not until this fresh impulse was given to the subject that Ruhmkorff commenced to make superior coils in Paris, since which, we believe, his coils have been carried to a high degree of perfection, and the secondary circuits are now made of the immense length of 100,000 meters, (upwards of sixty miles.) From the description of their performance by Mr. Noad in his Inductorium, (page 43,) we find but little increase of spark over the Ritchie coil made for Mr. Gassiot in 1857. The following interesting statement of Prof. MacCulloch, accompanying a communication from Mr. Ritchie, to the Journal of the Franklin Institute, (vol. 73, page 58,) 1862, shows that Ruhmkorff adopted Mr. Ritchie's mode of winding the coil, which we have already described in Part I, and it is evident that it was the source of his success. We shall allude to this again.

For the Journal of the Franklin Institute.

On Electrical Machines. By E. S. RITCHIE.

The electrical machine known as the Ruhmkorff Induction Coil, resulted from the researches and discoveries of Faraday, Henry, De la Rive, Fizeau, and others.

Mr. Ruhmkorff, of Paris, was the first to construct this instrument, following the arrangement of Faraday, surrounding an electro-magnet by a helix of insulated copper wire, to which he applied the automatic interrupter of De la Rive.

The important discovery of the action of the condenser to the interrupter, by which the intensity of the induced current is increased so as to pass an interval, is due to Fizeau, and was immediately adopted by Ruhmkorff.

The limit which Ruhmkorff attained in his most powerful coils was to throw the spark less than one inch.

Mr. Hearder, in 1857, improved the apparatus by more carefully insulating the helices, and obtained sparks of three inches.

During the spring of 1857, I attempted the construction of the instrument, following the general form adopted by Ruhmkorff; but, beyond the narrow limit already attained, I found it impossible to make one which would not destroy itself by the discharge taking place within the helix, between the outer and inner portions, which were necessarily brought in near proximity, depending alone upon insulating media.

I saw that this was an insuperable difficulty unless a mode of construction could be devised by which the portions of the helix should be separated by a distance nearly equal to the tension of the electricity induced in the wire. I wound a coil with the strata laid in conical form, each course beginning upon the bobbin, and winding up a cone of 45° until the diameter of the exterior was attained; then an insulation of rubber was overlaid, and another course wound in like manner, and so on: the experiment proved successful. I then devised a mode of winding the wire in planes perpendicular to the axis, alternately running from the inner to the outer, and from the outer to the inner diameters of the helix, insulating between the strata; and, in July, 1857, instruments were made giving sparks twelve inches in length.

Prof. Wm. B. Rogers, at the meeting of the British Association held in Dublin, in 1857, stated the power of my coils, and soon afterwards I received from John P. Gassiot, V. P. R. S., and from Prof. Forbes of the University of Edinburgh, orders for instruments of twelve and nine inches, which were sent them the following spring.

Until July, 1859, no instruments had been made by Ruhmkorff of greater power than three or four inches in length of spark, when he received one of my coils, which he dissected and copied, as will be evidenced by the following

Statements by Prof. MacCulloch.

1. In the summer of 1858, I ordered of Mr. Ruhmkorff one of his induction coils, similar to that for which the Academy had awarded him a prize. In my letter, I stated that Mr. Ritchie professed himself ready to surpass it whatever might be its power, and mentioned that he had made for Columbia College a coil giving twelve inches sparks, with a pile of four carbon cells. In the reply of Mr. Haskell (my Paris correspondent) it was stated that Ruhmkorff expressed surprise that this result had been obtained from four cells only. He did not accept the challenge, but agreed to make one of his best and most powerful coils with other miscellaneous apparatus.

2. In May, 1859, having obtained nothing from Mr. Ruhmkorff, I visited him in Paris, and urged the prompt execution of my order; he considered my request that he should send to New York a machine to be surpassed by one of a competitor as an unfair proposition. To this I replied that I would request Mr. Ritchie to send to Paris the most powerful coil he could make. With reference to my order for a large coil, he showed

me the wreck of the only one he had attempted to make, and informed me that it had destroyed itself by the spark passing through the coil, breaking down the insulation, &c., and he was unwilling to make any but his ordinary coils, (price 300 francs,) which, however, with other apparatus, he agreed to furnish promptly.

3. Supposing that Mr. Ruhmkorff would be happy to compare the coil of Ritchie with his own and that of Hearder, desiring to gratify him, and not for an instant doubting that he would accord to Ritchie all that is peculiar in his perpendicular system of winding the secondary bobbin, I presented to Mr. Ruhmkorff, in July, 1859, one of Ritchie's coils giving sparks of seven inches, which he dissected, for the purpose of examining its construction.

4. About the same time, I ordered from Mr. Ritchie the most powerful coil he could make, and requested him to send it to Paris. This instrument arrived in September, but was in the hands of the Custom House officers until November. When received it was taken to Mr. Duboscq's, who politely offered me the requisite facilities for experimenting with it. It was tried in the presence of Mr. Jacobi, of St. Petersburgh, and of MM. Foucault, Lipajous, Nachet, and Duboscq. Afterwards it was exhibited privately to MM. Jamin, Sénanmont, Verdet, Desains, Froment, Du Moncel, Baron Thénard, Gavarret, and others, and publicly to the students of the École de Médecine. By request of M. Jamin, it was also shown to the general commanding and several of the professors of the Polytechnic school.

5. During the month of February, 1860, I met M. Jamin, who told me that the Polytechnic school had for more than two years urged M. Ruhmkorff in vain to make for its cabinet a powerful coil; that in the month of March it would be necessary to close the account of expenditures for the fiscal year, and that unless Ruhmkorff should then deliver the long-solicited coil, the Polytechnic school would be glad to buy that of Mr. Ritchie. In the month of March, Mr. Ruhmkorff delivered to the Polytechnic school the coil ordered from him.

6. In May I saw the said coil at the Polytechnic school, and was informed by M. Jamin that the secondary bobbin is wound in portions perpendicular to its axis (Ritchie's system;) also, that it gave sparks of 33 to 40 centimetres, (13 to 16 inches,) about the same as those of Mr. Ritchie's coil.

7. In June, Mr. Ruhmkorff showed me in action a coil just finished by him for M. Du Moncel, a duplicate of that of the Polytechnic school. The sparks were of about the average length of those from the Ritchie coil. Mr. Ruhmkorff gave me as the length of the sparks for both the coil of the Polytechnic school and that of M. Du Moncel, 33 to 40 centimetres; and he stated that the secondary bobbin is divided (fractionné) perpendicular to the axis. * * * * * * * * * *

(Signed) R. S. MacCulloch.

New York, September 8th, 1860.

The French scientific journals immediately noticed the instruments made by Mr. Ruhmkorff, awarding to him the credit of all the improvements made. The Vte. Du Moncel, Ganot, and other French writers who have published descriptions of the instrument, though fully conversant with the facts, have carefully ignored them. Prof. MacCulloch wrote to Vte. Du Moncel to correct statements in the *Cosmos* which he considered unjust to me, but no notice was taken of his request.

I am induced to make this statement only because my silence has been construed into an admission that I had made claims which I could not substantiate.

Boston, December 15th 1861.

Recurring to the subject of the condenser, many opinions have been offered in explanation of the true nature of its action, but thus far it seems that no one has met with general assent. Its author, Fizeau, offered a very simple explanation, and one that has not yet been improved upon. He says: "As soon as the points of the interrupter are separated, the two free electricities of the wire run into the plates of the condenser," and are thus withdrawn from the extra current.

Ferguson, in his recent work on Electricity, 1867, (page 189,) remarks as follows: The condenser of the coil machine has for its object the absorption or suppression of the extra current, but the manner in which it effects this is not yet properly explained. The prejudicial effect of the extra current on the induced current is easily understood, when we bear in mind that it prolongs the cessation of the magnetism of the core, and of the current in the primary coil, and thus impairing the suddenness of this change, reduces the tension of the induced current. The opinions of Fizeau, Faraday, and Poggendorff, are given by Mr. Noad in his Manual of Electricity, (page 730,) 1857, with the remark that "the function of the condenser is not clearly understood." In his Inductorium, he quotes the opinion of Mr. Hearder. In the Lond. Ed. Mag. for November, 1857, (page 339,) Prof. Callan advances also a peculiar theory, which we will not now discuss. Whatever theories, however, may have been advanced, all writers agree as to the effect, which is, to arrest or prevent the full flow of the extra current, or the secondary current of the primary wire, and that as soon as the condenser is connected with the primary circuit, the brilliant sparks of the circuit-breaker are at once diminished. We have already shown the great power of the condenser, in absorbing the free electricity of a galvanic battery, and it is to be presumed this is the case, whether the poles of the battery are connected with a long or short wire. Indeed, Masson and Breguet asserted that the condenser was more readily charged when a long coil was interposed, the poles of the battery in this case being disconnected. The manner of connecting the condenser with the circuit—that is, on each side of the circuit-breaker, does not admit of its being charged even to a feeble, certainly not an appreciable degree. But the instant the circuit is opened, the condenser is then in connection with the two poles of the battery, the primary coil being included. It absorbs at once the free electricity of the battery, and that of the secondary current of the primary coil, which otherwise would have passed through the heated atmosphere caused by the spark and combustion or ignition of the metal of the circuit-breaker at the point of separation. The duration and length of this secondary spark depends upon the *rate* of subsidence in the magnetic power of the core; and as the flowing of the secondary prolongs the magnetism, it is evident that the secondary must be suddenly arrested in some way, in order to allow a sudden relapse of the magnetic forces. Prof. Page has shown, as we have before noticed, that the secondary spark or current was in certain instances prolonged to a second or more, and that the spark itself passed through *eight inches in air.* (Sill's Journal, vol. 11, No. 33, page 191, 1851.) Any device, therefore, for the sudden and complete neutralization of the magnetism, will increase the power of the secondary, and this was accomplished by the discovery made by Prof. Page of the property of the bundle of iron wires in place of the solid bar, and its application to the electro-static coil. As we have before noticed, this discovery was made by Mr. Bachhoffner, in Europe, a short time previous. Now, the inductive energy of the magnetic forces is extended to the secondary circuit, as well as the primary, and the secondary current of this circuit also reacts upon the magnetic forces, to retard their relapse. Hence, if the secondary circuit be closed—that is, the ends of its wire joined, only a slight spark will be obtained on breaking the primary circuit, for prolongation of the magnetism prevents any sudden development in the primary wire of its electricity. This action was beautifully illustrated by Prof. Page, with his magneto-electric multiplier, in 1838, (Sill's Jour., vol. 34, No. 2, page 372,) by causing the closed secondary circuit to prolong the magnetism of the core, so as either to retard or accelerate the motion of the revolving armature, according to the relative position of the core and armature, at the time the circuit was broken. It follows directly from this, that, to obtain full and sudden reaction upon the secondary circuit, the sudden cessation or abatement of the magnetizing power of the primary current demands our attention also. It is true that the same necessity would exist if the primary circuit did not inclose a magnet, though not to so great an extent, for the coil deports itself precisely like a magnet of feeble power. The means of thus suddenly arresting the secondary of the primary were discovered by Prof. Page, in 1836, and its effects noted in exalting the power or intensity of the secondary current. They consisted in breaking the circuit of the primary under a non-conducting liquid over the surface of mercury or a solid conductor. (Sill's Jour., vol. 31., page 140, and in several subsequent volumes, as heretofore mentioned.) Thus, the two cardinal principles, upon which the great power of the secondary coils depends, viz: the compound-magnet in place of the solid bar, and the sudden arrest of the primary current, were discovered by Prof. Page, and were, together with other original improvements, embodied in an electrostatic coil in the early part of 1838, (see Fig. 2.) After the coil of Ruhmkorff was made known, Poggendorff, in Germany, undertook, by a series of experiments, to ascertain the operation of the Fizeau condenser. To this end he removed the condenser, and plunged the circuit-breaker, while working, into various liquids. He found that in a conducting liquid, such as acidulated water, the secondary spark was very feeble. In a perfect non-conductor, such as oil of turpentine, the sparks were still feeble, as in the air, but, in a liquid of a low degree of conducting power, such as pure water or alcohol, the induction sparks were very strong, the same as with the condenser.

He found also, that by using a very long and fine wire of great resistance in place of the condenser, it had the effect of the condenser. With a secondary coil of 10,000 feet of fine wire, a resistance coil of 10.000 feet of the same wire produced a marked effect. With a secondary of 10,000 feet, however, he found that 1,200 feet of wire ¼ millimeter in diameter produced some, though less effect. Also, that by breaking the primary circuit in a vacuum of 3 to 4 millimeters, mercury pressure, the secondary was increased. In regard to the operation of the non-conducting liquids, there was a very strange anomaly, viz: that a poor conductor should arrest the primary current, and that a real non-conductor should not arrest it. The truth is, that Poggendorff made some mistake in his experiments about the action in the oil of turpentine. It will be remembered that, according to the accounts we have given, Dr. Page found that water, and even naptha, would increase the secondary, but that oil, (good sperm oil,) was better than either. We have found that oil of turpentine operates with better results than any liquid tried, although we do not use it often, because of its viscid nature, and its causing the circuit-breaker to work irregularly, the turpentine becoming adhesive, and occasionally preventing good contact; but while it does work, the secondary sparks are more intense than when any other liquid is used. It is probable that, in Poggendorff's experiment, the turpentine got between the hammer and anvil of the circuit-breaker, and prevented good battery contact. This is very likely, as he used the McGauley circuit-breaker, adopted by Ruhmkorff, which had no means of adjusting the retractile force of the hammer or pressure between the points of contact, and hence, if turpentine got between them, there was not force enough to press it out, so as to allow the metals to come into good contact. These experiments, made in 1854, were only corroborative of Professor Page's discovery in 1856, of which Poggendorff does not seem to have been aware. Of course it would have been impracticable to have operated the circuit-breaker in this way. Foucault, however, in 1856, with a view to make this principle available, introduced a mercurial circuit-breaker of the independent class, the mercury being covered with pure water or alcohol. We have before adverted to this circuit-breaker in its appropriate place, and shown it to be identical in principle and operation with that of Professor Page's coil of 1836. See Fig. 2. There was such a remarkable coincidence in this case, that even the mode of regulating the retractile force of the hammer by the sliding weight, a device entirely peculiar to the Page circuit breaker, was adopted by Foucault. This independent circuit-breaker, distinguished as the "*Foucault circuit-breaker,*" is now imported into this country with the coils of Ruhmkorff. It is probable that neither Ruhmkorff, Poggendorff, Foucault, nor any of the French authors who have written on this subject, had any knowledge whatever of the anticipation of these improvements, or any part of the whole subject, by Professor Page. Nevertheless, the entire ignorance in France of what had been so long published in this country and England, is very extraordinary in relation to this particular department of electricity, and in no instance more so than in regard to the electrostatic properties of the secondary current. Although the fact had been known to almost every individual interested in electricity who read the English language, (Mr. Noad seems to have been an exception,) that all the electrostatic properties of the secondary circuit, viz: the shock, charging a Leyden jar, diverging the gold leaves of the electroscope without a condenser, and the projection of a spark before contact, had been demonstrated nearly twenty years before, yet Du Moncel and Becquerel, and others, taking the cue from them, announced, in 1856, that Masson and Breguet were the first to observe analogies between, and, in fact, to establish the identity of the secondary circuit and static electricity, while at the same time they confessed that they could not produce the least spark projected before contact. Although it was commonly known in England and America, even thirteen years before Ruhmkorff made his first coil, that electrical sparks were given by the secondary coil, it was regarded as a novelty in France in 1851. Notwithstanding the interesting fact published by Mr. Gassiot in 1841, which we have before noticed—a fact presumed to have been known to every observant electrician—that, with a well insulated secondary coil, *twelve miles in length*, he obtained strong sparks in air, and sparks *three-quarters of an inch* in length in the flame of a spirit lamp, the announcement in France of a spark by the coil of Ruhmkorff, which we think was not more than one-eighth of an inch long, was there regarded as a new discovery, and not the remotest allusion was ever made to the fact of its having been produced elsewhere, although, as late as 1856, Du Moncel and Becquerel emphatically state that Masson and Brequet, in 1842, failed to obtain a spark in air—a failure which elicited the remark from Du

Moncel that, although "their experiments justified the belief that Voltaic electricity could be transformed into static electricity, yet the question was not practically solved, and the electrical machines were not yet dethroned."

The use of the condenser to increase the power of the secondary should be regarded as original with Fizeau. Condensers had long before been used to absorb the static-electricity of the galvanic battery, and had also been used with a primary coil alone, as in Masson and Breguet's experiments, but no notice had been taken of its effect upon the secondary current. Mr. Sturgeon (Sturg. Annals, vol. 1, page 80, 1836,) describes a condenser used with a magneto-electric machine of Mr. Rainey. The condenser was precisely like those used with the coils of Ruhmkorff and others. In reality, it was a true Fizeau condenser. "It consisted of three yards of varnished silk, coated on both sides with tin foil, and rolled up with a ply of silk intervening." "One of these coatings being connected with the positive, and the other with the negative part of the machine, the silk became charged as decidedly as glass is by the common electric machine, but the intensity was very low. The spark was much finer by this means than from the coils alone." The meaning of this last remark is very doubtful. Mr. Sturgeon had previously described a very extensive condenser of his own, made of varnished Bristol board cut into plates and coated with tin foil. This was for use with a galvanic battery. In 1852 M. Sinsteden suggested the use of a condenser with the secondary coil, and not the primary. Several electricians have testified that they used a condenser made of copper ribbons, wound into a spiral, with Page's induction apparatus, as early as 1840, and that its use was attended with marked effects. The affidavits of N. B. Chamberlain, Henry B. Chamberlain, Moses G. Farmer, Thomas Hall, and Prof. Wm. C. Richards, attached to a memorial of Prof. Page before Congress, all testify to this use of the spiral condenser at a very early period. They also state that its use was suggested by Prof. Page. Of this very important fact we find no record whatever; and as this is the kind of proof demanded by the rule of credit which we have set up in this treatise, and which, in fact, the scientific world would exact in establishing the origin of a discovery so interesting and valuable as this, we must concede the merit of the condenser to Fizeau. The single flat spiral, especially if of great length, would operate to some extent as a condenser, upon the same principle as the long fine wire used by Poggendorff. as a substitute for the condenser; but the double flat spiral is a true condenser, and this was made by Prof. Page as early as 1838. One of these is described in Silliman's Journal, by him, in 1846, as having been made eight years before, of sheet zinc insulated with rubber cloth. (Silliman's Journal, 2d series, vol. 11, No. 5, page 204.) We may mention incidentally here, that we find in his private notes a description of a double flat spiral of copper ribbon, in 1838, but we do not find anywhere any reference to its use as a condenser, with the primary coil to increase the intensity of the secondary.

There is one fact, however, stated by Mr. N. B. Chamberlain which must be accepted, and which establishes the merit of Prof. Page's induction coils, made prior to 1842. He states that, with some of the Page coils made prior to 1842, he obtained "flashes of electricity through a vacuum tube *twelve or fifteen* inches in length. It may be remarked, in this connection, that all of Prof. Page's experiments and improvements prior to the middle of 1838, were made in Boston and the neighboring city of Salem, and that the Boston instrument-makers were, more than any others, familiar with his manipulations. They knew from his descriptions, publications, and, above all, from the performance of the instruments which they saw and made, that the electrostatic powers of the induction coil had been fully proved and conclusively shown by the Page coils, and were not long in enlarging and improving those coils. They were not possessed then of those two very efficient insulators, viz: gutta percha, and vulcanite or hard rubber, by the use of which, we do not now find it necessary to make large coils for the display of the electro-statical phenomena. We have now miniature coils three inches long and one inch in diameter, giving sparks, even without a condenser, of half an inch, and lighting vacuum tubes three or four inches long, and in fact more than double the intensity of Ruhmkorff's first great coils.

THE RUHMKORFF COIL.

On the 23d February, 1852, the Emperor of France offered a prize of 50,000 francs, to be bestowed after five years, to the author of the most important discovery concerning the applications of electricity, and a commission composed of thirteen eminent men of science was appointed to adjudge the award. In 1857 the Commission reported that they had not found any discovery worthy of the prize, and prayed that the time might be extended for five years more. In 18~~5~~4 they reported in favor of the award to M. Ruhmkorff, the inventor of the "coil bearing his name." The members of the Commission awarding this prize to Ruhmkorff were as follows: 6/

Dumas—membre de l'Institut—President.
Pelouze, " "
Regnault, " "
Rayer, " "
Serres, " "
Becquerel, " "
Le baron Ch. Dupin, " "
Le baron Seguier, " "
Le General Morin, " "
Le General Pisbert, " "
Henri Sainte Claire Deville, "

Reynaud—inspecteur-general des ponts et chausses, chef
du service des phares.

Jamin—professeur de physique a la Faculte des Sciences.

In view of all the facts of record laid before us in this work, we are at loss to see how Ruhmkorff could have come within the provisions of the offer of the prize, which was to be given to the "author of the most important discovery," etc. We do not understand that the prize was to be confined to France; and as we have clearly shown, by irrefragable records, that Ruhmkorff was not the originator of any invention, discovery, principle, or improvement connected with the induction coil bearing his name, it would seem that the Commission took it for granted that the coil, with all its beautiful developments, was entirely the work of Ruhmkorff, save and except, Fizeau's condenser and Foucault's circuit-breaker, which were unavoidably known to them and regarded as French inventions, and the circuit-breaker, which was acknowledged to be the invention of another, and called the Neef circuit-breaker. Proceeding upon such an assumption, it would seem that no investigation was made as to what had been done outside of France, in reference to the electrostatic coil. This supposition seems to be supported by the fact that Becquerel, a distinguished electrician, who was a member of the Commission, in Traité d'Electricité et de Magnetisme—edition of 1856, vol. 3, page 241—when about to describe the Ruhmkorff coil, says: "It was Masson and Breguet who proved, *beyond a doubt*, the tension of the induced or secondary current by their experiments made in 1842;" "but they did not obtain a spark passing through a distance in air." ("Mais ils n'obtinrent pas d'etincelle eclatant a distance dans l'air.") The inference is, that the spark was regarded as the discovery of Ruhmkorff. This defective link in the chain of evidence, necessary to a full recognition of the identity of the two forces, was presumed to have been supplied by him, for no allusion whatever is made by French authors even up to the time of the award in 1864, even to an attempt to obtain a spark by any one in England or elsewhere. The oversight is certainly remarkable, and savorss trongly of favoritism. But our surprise does not stop here. The statement of Professor MacCulloch, which was published in January, 1862, in the Journal of the Franklin Institute, and which we have copied in full, shows that the signal improvement of Mr. Ritchie in winding the secondary wire was brought to the attention in November, 1859, of many distinguished men of science in Paris, among whom was Jamin, one of the members of the Commission awarding the prize. It shows also, that in July, 1859, Ruhmkorff dissected one of Mr. Ritchie's coils, and learning its construction, afterwards adopted it as his own—that is to say, he made very powerful coils by the aid of this valuable improvement, without giving credit to Mr. Ritchie for it, and permitted them to pass to his own credit, by suppressing the name of the rightful discoverer. The reader is referred for further details to that statement of Professor MacCulloch, which is discreditable to Ruhmkorff, detracts largely from the meritorious character of this award by the Commission, and most decidedly from the magnanimity of Jamin, one of its members, who was fully aware of the superior advantages gained by Ritchie's improvement, and of the adoption of the same by Ruhmkorff. It cannot be denied that the improvement of winding the secondary coil perpendicular to its axis was original with Mr. Ritchie, nor can it be argued, *seriously*, that the improvement was but the carrying out *in extenso* of Bright's or Poggendorff's plan of dividing the whole coil into several sections, "each section being wound in the usual way of winding the whole coil"—that is to say, winding the wire back and forth horizontally or parallel to the axis of the coil.

It is sometimes difficult to draw a boundary line, and to say precisely where an invention begins and ends, where the improvement is one of degree, and not of distinctive kind. In this case, there is no such difficulty, and the suggestion of Poggendorff himself fixes the line of demarcation. He proposed to make "several sections, each section to be wound in the *usual way* of making coils." Mr. Ritchie made sections, each section of which *could not* be wound in the *usual way* of making coils. It is the introduction of a distinct principle of construction, necessitating very distinct mechanical manipulation, and, if measured by the results obtained at that time, there was just the difference between them, which was exhibited by a Ruhmkorff coil of "four inches spark," and a Ritchie coil of "13 to 16 inches spark." This distinction is derived from the facts of the statement. Mr. Ritchie states that "up to July, 1859, Ruhmkorff had made no coils of greater power, than three to four inches sparks," and he evidently speaks understandingly, for by Prof. MacCulloch's statement, in May 1859, Ruhmkorff declined to make any coils except his ordinary coils, (price 300 francs;) for, in his attempt to exceed these, the "coils destroyed themselves" by rupturing the insulation. A year before this time, as will be seen in the first part of this work, Mr. Gassiot published an account of a coil received by him from Mr. Ritchie, which gave 12¼ inch sparks by actual measurement, and would, he had no doubt, give 15 inches, but he was afraid to force it. Gassiot, in describing this coil, put the instrument-makers in Europe on the wrong track, by stating that the coil was divided in sections, according to Poggendorff's suggestion. Ruhmkorff appropriately characterizes Ritchie's mode of winding the coils as *fractionné*, and we might call the other mode of large divisions as *sectionné*, the difference between them being thus well expressed, and as Mr. Ritchie adopted both modes in the same coil, the success of his instruments might have been attributed to the sectional arrangement, which was apparent, while the fractionnē secret required *dissection* to reveal it, which operation Ruhmkorff performed on a Ritchie coil, presented to him in July, 1859, by Prof. MacCulloch. Finally, we regret to include Du Moncel, whose authority we have quoted so often, among those who yielded to national prejudice in this matter. In the preface of his work on the applications of electricity, 1856, he starts with the following motto: "I have sought as far as possible to be impartial, and *to render to Cæsar the things which belong to Cæsar*." From MacCulloch's statement, Du Moncel was among the number to whom the Ritchie improvement was exhibited in Paris, before Ruhmkorff commenced his *new era* in coils, and if, as the statement avers, he failed to do Mr. Ritchie justice, he too, is open to the charge of favoritism, or at least inconsistency with his professions of impartiality.

In conclusion, we remark, that in our own dissection of the coil, we may have laid ourselves liable to the imputation of partiality. If so, it is not because of the *suppression* of any fact within our knowledge or reach that might inure to the benefit of any contributor to this branch of electrical science. Although the primal inducement to this investigation and publication was the establishment of certain claims of its author hitherto not only unrecognized, but actually ceded to others, by a loose acceptance of historical evidences, and although we have had much to say of the discoveries and inventions of Prof. Page, still we have endeavored to make a complete and impartial record of every fact having any important bearing upon the claims of others. We have brought to light important claims of others hitherto unrecognized, have corrected some very important anachronisms of authors, which have or might have been fruitful sources of error, and subverted some titles of long standing, by indisputable records. We will advert only to one instance in point. When we commenced this work, it was supposed in this country that the hammer circuit-breaker was the invention of Dr. Page, as it was completed by him in April, 1838, and was on sale and advertised some months before its description was published by Dr. Neef, to whose credit it passed in Europe. We have been compelled to acknowledge priority in favor of Prof. McGauley, of Ireland, and although his name has never been mentioned by any English author in this connection, we have found that he was in our advance more than six months, by a full description and illustration of the invention, and, what is quite remarkable, that as early as October, 1837, this invention was before the London Electrical Society in actual operation, introduced by Dr. Golding Bird, who stated that it was "not his own invention," without giving the name of the originator. Its origin has been fully explained under the subject of circuit-breakers.

In concluding the first and second parts of this work, we have specified the particulars in which Prof. Page had anticipated all others by his discoveries and inventions, in relation to the subject of induction and the electrostatic coil.

From a review of the whole, we find—

First. That the first electrostatic coil was the invention of Prof. Page.

Second. That the principle upon which the present success of the electrostatic coil depends, was first discovered and applied by Prof. Page. That principle being the sudden arrest or prevention of the flow of the current in the primary coil, the condenser of Fizeau being included under that principle. And although the latter modification is more effectual than the spark arresting circuit-breaker of Prof. Page, still the suppression of the primary or extra current is the object alike of both.

Third. That, with the exception of the condenser of Fizeau, the electrostatic coil is an American invention, and that the so-called Ruhmkorff coil was commenced and perfected in the United States. It was commenced and so far advanced by Prof. Page as to develop its *electrostatic* properties, and was consummated in the development of those properties to an extent far exceeding anything known in Europe, by Edward S. Ritchie, of Boston, Massachusetts.

Fourth. In regard to the magneto-electric current, its identification with static electricity was first established by Prof. Page. He also first indicated the way in which the magneto-electric machine could be used to obtain the electric light. (Sill's Journal, vol. 35, No. 2, page 252, November, 1838.)

The thermo-electric spark was also first obtained by Prof. Page, thus completing its identification with electricity from other sources.

For reference to the numerous papers published by Prof. Page on the subjects of Electricity and Magnetism, the reader is referred to their synopsis in Poggendorff's Biography and Literature of Men of Science.

CHAS. G. PAGE, M. D.
Late Prof. Chem. and Phar.,
National Medical College.

WASHINGTON, D. C., *December* 24, 1867.

The following is a list of the inventions of Prof. Page figured in Davis' Manual of Magnetism. For some of these credit is given in the 1847 edition, and for some omitted:

Fig. 69—Revolving Coil.

Fig. 70—Pole Changer.

Fig. 115—Magnet Revolving on its axis without mercurial connections.

Fig. 118—Rotary Axial Engine, (secured by patent in 1863.) No credit given.

Fig. 122, 123, 125—Axial Engines. (See remark in section 294.)

128—No credit given. (See Sill's Journal, vol. 35, page 261.)

140—Reciprocating Armature Engine.

142—Revolving Armature.

146—Revolving Magnet, credited in edition of 1842.

153, 154—Revolving Wheels or Discs.

162—Revolving Coil.

174—Magneto-Electric Machine.

179—Induction Coil Apparatus.

182—Medical Instrument.

183—(See Sill's Journal, vol. 35, page 258.) Also editions of 1842, 1839, 1838.

179—Figured in 1842, with Page's Circuit-Breaker attached.

C. G. P.

APPENDIX

TO

SECTION ON MAGNETO-ELECTRIC MACHINES.

One of the first fruits of the double machine was the demonstration by Prof. Page of the conversion of mechanical into electric or magnetic force. Soon after the announcement, last year, of the magnificent results from Mr. Wilde's new magneto-electric machines, the question arose in England as to who first produced, by the magneto-electric machine, an electro-magnet exceeding in power the permanent magnets used in the machine as the source of the magnetizing current. This was first accomplished by Prof. Page, in 1843. The peculiar machine is figured and partly described in Vail's work on the Electro-Magnetic Telegraph, 1845, page 147; also in Silliman's Journal, vol. 48, p. 393; also in the report of the Commissioner of Patents for 1844. The helix of this machine was not described in those works, for reasons alleged, and was of a novel construction. It was called the plate helix, being made up of a series of copper discs, instead of wires, each disc being split, and one of its split edges joined to the edge of the adjoining disc. It would be represented in miniature by a very broad, flat, thin screw thread. The helices were very large, and, when inclosed in a cylinder of pasteboard, as shown in Vail's work, for the purpose of avoiding the resistance from the air, they presented the form of a drum nearly two feet in diameter. The object, sought was to realize the maximum of quantity, with a comparatively low intensity. The distinguishing feature of this machine was its power to create an electro-magnet sustaining *a thousand pounds,* while the exciting magnets sustained only about one hundred and twenty-five pounds. It required the full strength of a man to turn it rapidly. It is to be regretted that the power of the permanent magnets was not mentioned at the time; but, as the machine and its electro magnet was presented, together with a description, to the Smithsonian Institution, in 1852, and occupied a prominent position in its cabinets until the recent fire, by which it was destroyed, we will state here the fact that the steel magnets weighed about sixty pounds each, and when first charged would each sustain its own weight, and that the combined lifting power was not at any time more than one hundred and thirty pounds. The description of Wilde's machine before the Royal Society notices the Page machine. The following is a copy of the letter of the Secretary of the Smithsonian Institution:

SMITHSONIAN INSTITUTION, *May*, 13, 1852.

DR. PAGE—

DEAR SIR: At the last meeting of the Board, held on Saturday, May 1st, 1852, I was directed to return the thanks of the Institution for your valuable donation of a magneto-electrical machine, intended to produce a large quantity of electricity of low intensity. The instrument will be carefully preserved as a part of the apparatus of the Institution.

I have the honor to be, very truly, your obedient servant,

JOSEPH HENRY, *Sec'y S. I.*

*PB-45456-SB
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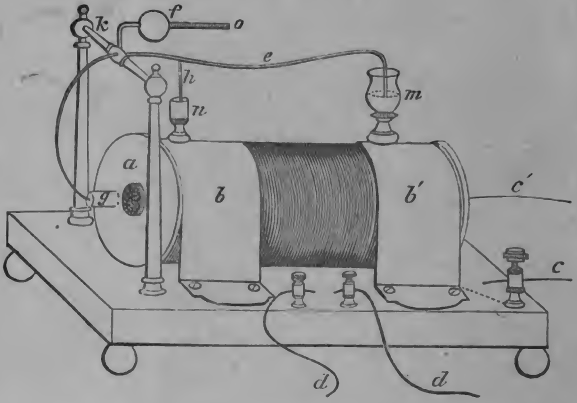
FIG. 2.



Page's Electrostatic Coil. April, 1838.

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